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Evaluation of Osteochondritis Dissecans of the Knee in Children with MRI. Arthroscopic Fixation with Bioabsorbable Chondral Darts. A Retrospective Study of 32 Knees

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SUMMARY
Osteochondritis Dissecans (OCD) is an idiopathic, well-localized, pathological condition affecting the articular subchondral bone, and its overlying cartilage. In some cases it can progress to the detachment of the affected osteochondral region. Evaluating the stability of the lesion is a key part of providing the correct treatment. Stable lesions, particularly in juvenile patients, have a greater tendency to heal with non-surgical treatment, whereas unstable lesions usually require surgical management. The evaluation of instability of the affected osteochondral region can be assessed by magnetic resonance imaging and arthroscopy.
A total of 32 skeletally immature knees sustained OCD were included in this study. Each knee was evaluated for potential OCD instability by MRI and arthroscopy. The bioabsorbable chondral darts were used for the fixation of the thirty-two osteochondral fragments, to secure their stability and mainly to stimulate their healing. For evaluation of the knee function preoperatively and postoperatively we used the online International Knee Documentation Committee (IKDC) system.
The mean patient age at the time of surgery was 12.64 ± 0.98 years (range 10-14 years). The average follow-up was 2.58 ± 0.71 years (range, 2-4) years. The mean preoperative IKDC score was 31.67 ± 8.36 (range, 23-45) points. The mean postoperative IKDC score was 83.5 ± 1.52 (range, 81-86) points. The 2-tailed P-value < 0.001 was statistically significant.
MRI and arthroscopy are valuable tools for assessing the instability of the OCD lesion and its healing potential. The bioabsorbable chondral dart implant provides secure fixation and compression of the osteochondral fragment, increasing its healing potential.

KEY WORDS
Osteochondritis dissecans; MRI; arthroscopy; chondral darts; knee.

INTRODUCTION

Osteochondritis Dissecans (OCD) is an idiopathic, well-localized, pathological condition affecting the articular subchondral bone, and secondarily its overlying cartilage. This focal pathological condition can progress in some cases to the detachment of the affected osteochondral region. The cause of OCD remains controversial (1-4). Although several causes have been hypothesized, including inflammation, genetics, ischemia, ossification, and recurrent trauma, insufficient evidence remains to definitively support any of these causes for the time being. In addition, typical, "idiopathic" OCD must be differentiated from similar-appearing osteochondral lesions resulting from avascular necrosis associated with chemotherapy, hemoglobinopathy, and steroid

use. The Micro-trauma hypothesis is by far supported by the best level of evidence for typical OCD. There have been many reports in the literature regarding the potential role of trauma (either acute microtrauma or repetitive microtrauma) in the development of OCD, particularly because of the increasing prevalence among athletes (5). The incidence of this condition has been influenced in recent times by growing participation in competitive sports by children at younger ages across both genders (1). As a result, the mean age of the OCD onset seems to be decreasing, along with an increased prevalence among girls (1). The most affected joint is the knee joint, with the posterior lateral aspect of the medial femoral condyle being the most affected region in 70% of cases. Follows at a frequency the lateral femoral condyle in 20% of cases and the patella in 10% of cases. OCD is bilateral in 20-30% of cases. Symptoms are variable and range from the pain that is vague, poorly localized, and related to activity, to significant pain and locking (suggesting loose body formation). Unstable lesions are distinguishable by the presence of mechanical symptoms, and knee effusion. On physical examination, an antalgic, external rotation gait may be observed. On palpation, maximal tenderness can often be elicited over the anteromedial aspect of the knee with varying amounts of knee flexion. This corresponds to the most common site of the OCD lesions on the lateral aspect of the distal medial femoral condyle. Pain may be provoked with internal rotation of the tibia (Wilson sign). Atrophy of the quadriceps muscles provides a good indication of how long the lesion has been present. Evaluating the stability of the lesion is a key part of providing the correct treatment. Stable lesions, particularly in juvenile patients, have a greater tendency to heal with non-surgical treatment, whereas unstable lesions usually require surgical management. The evaluation of instability of the affected osteochondral region can be assessed by magnetic resonance imaging and arthroscopy. The assessment of the instability of the affected osteochondral region can be done with MRI by using the International Cartilage Repair Society System (ICRS classification system for OCD lesions) (**table I**). The ICRS was founded in 1997 (6, 7). MRI is useful for the assessment of the fragment's articular cartilage continuity and its potential instability (T2 weighted image: Type III , and IV), and for assessing the size and potential healing of its subchondral bone only by conservative means**.** In the T2 weighted image, the presence of a high signal at the interface between the osteochondral fragment and the underline bone is considered a bad prognostic sign of healing and indicates either granulation tissue or synovial fluid (MRI type, III, and IV). Arthroscopic exploration is the next necessary step for the confirmation of an unstable OCD lesion. The OCD lesions are classified based on articular cartilage integrity (open or closed) and the stability of the underlying subchondral bone and its bed (stable or unstable). The ICRS developed a four-grade classification based on findings upon inspection and palpation: Grade I: stable lesions with a continuous but softened area covered by intact cartilage. Grade II: lesions with partial discontinuity that are stable when probed. Grade III: lesions with a complete discontinuity that are not yet dislocated ("dead in situ"), and Grade IV: empty defects as well as defects with a dislocated fragment or a loose fragment within the bed (8) (**table II**). Drilling of the osteochondral lesion creates excellent outcomes if the lesion is stable. Unstable lesions require fixation. For loose but intact fragments with macroscopically normal cartilage surface and a layer of subchondral bone, fixation is also indicated.

Table I. ICRS TYPE, MRI evaluation for OCD lesions.

ICRS OCD I: small change on signal without clear margins of fragment
ICRS OCD II: osteochondral fragment with clear margins but without fluid between fragment and underline bone
ICRS OCD III: fluid is visible partially between fragment and underline bone
ICRS OCD IV: fluid is completely surrounding the fragment, but the fragment is still *in situ*
ICRS OCD V: fragment is completely detached and displaced (loose body)

Table II. ICRS STAGE, arthroscopic evaluation for OCD lesions.

ICRS OCD I: stable lesions with a continuous but softened area covered by intact cartilage
ICRS OCD II: lesions with partial discontinuity at the lesion and bone interface that are stable when probed
ICRS OCD III: lesions with a complete discontinuity that are not yet dislocated ("dead *in situ*")
ICRS OCD IV: empty defects with a dislocated fragment or a loose fragment within the bed.

MATERIALS AND METHODS

Between May 1990 and November 2017, a total of 64 consecutive immature patients (range 10-14 years old) (68 knees) had been referred to our institution with symptomatic OCD lesions for evaluation and treatment. Symptoms were variable and range from a pain that was vague, poorly localized, and related to activity, to significant pain and locking (suggesting loose body formation). The patients' knees were assessed first by clinical examination. The Knee OCD was then evaluated and classified according to its anatomical location and size with X-Rays (A/P, tunnel, and lateral view images) (**figure 1**). Next, the evaluation of the instability of the affected osteochondral region was made by magnetic resonance imaging (**figure 2**) using the International Cartilage Repair Society (ICRS Classification System for OCD Lesions) (**table I**). Twenty-eight patients (32 knees) who sustained symptomatic stable OCD, detected by MRI (ICRS Type I), responded very well to the conservative treatment they underwent (restraint of sports activities and immobilization of the knee for 6 weeks in a knee brace) and were excluded from our study. In four patients (4 knees), a free loose osteochondral fragment was detected by MRI (ICRS Type V) and confirmed by arthroscopy (ICRS stage IV). These four patients were excluded also from this study.

For the final evaluation of the OCD lesion, and its decisive treatment, an arthroscopic investigation was considered necessary in 36 knees. The arthroscopic findings were evaluated and classified using the International Cartilage Repair Society (ICRS) system (**table II**, **figure 3**). Surgical treatment to promote healing was performed on stable (immobile) lesions that did not respond to six months conservative treatment and on unstable (mobile) lesions. The patients' knee functionality was assessed by a subjective questionnaire (for pain and activity) and scored by using the online calculator of the International Knee Documentation Committee (IKDC) (87/87) system (4). The assessment was undertaken preoperatively and postoperatively, at 3, 6, and 12 months, and then at 6-month intervals. Postoperative MRI assessment was undertaken at 6, 12, 18, and 24 months postoperatively. The statistical analysis of the radiological, MRI, arthroscopic exploration, and patients' knee functionality results was performed by the author (M.P), with the contribution of the coauthor (M.O), using the SPSS v 23.0 software (SPSS Inc., Chicago, IL, USA). A paired t-test was used to analyze data, and a P-value of < 0.01 was considered statistically significant.

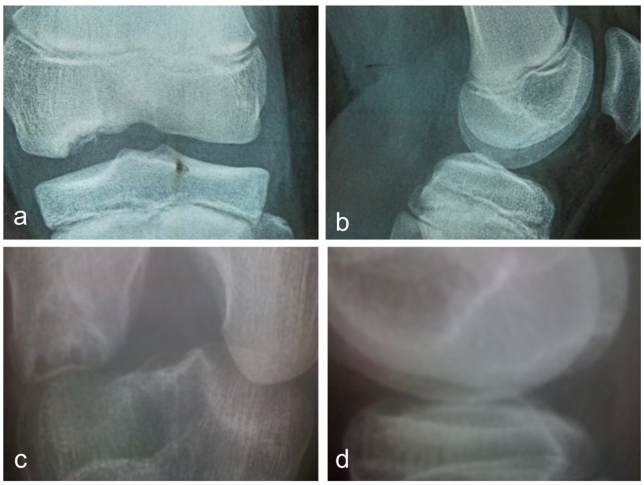

Figure 1. Evaluation of OCD lesion with X-Rays.

(a) OCD lesion of the medial femoral condyle, left knee, A/P view, **(b)** OCD lesion of the medial femoral condyle, left knee, Lateral view, **(c)** OCD lesion of the lateral femoral condyle, right knee, tunnel view, **(d)** OCD lesion of the lateral femoral condyle, right knee, lateral view.

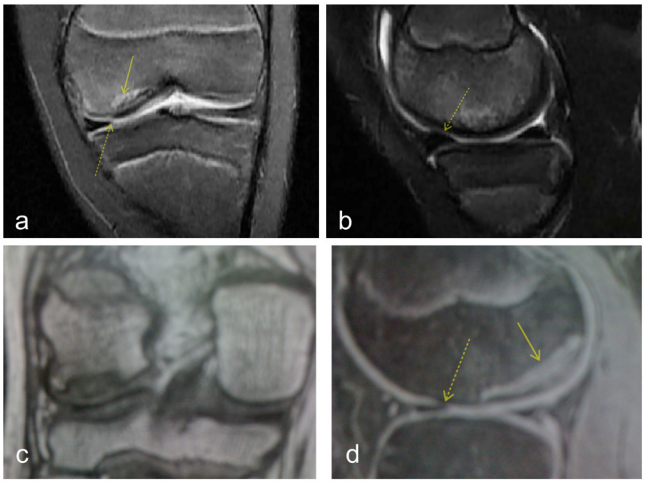

Figure 2. Evaluation of OCD lesion with MRI.

(a) OCD lesion of the medial femoral condyle, left knee, T2 weighted MRI image, coronal view. Solid arrow: high signal at the interface between the fragment and the parent bone indicates the presence of either granulation tissue or synovial fluid, and it is a bad prognostic sign of healing of the osteochondral lesion by conservative means. Dotted arrow: interruption of the continuity of the fragment's cartilage is a strong indication of the potential instability of the osteochondral fragment MRI ICRS type III. **(b)** OCD lesion of the medial femoral condyle, left knee, T2 weighted MRI image, sagittal view. Dotted arrow: interruption of the continuity of the fragment's cartilage. **(c)** OCD lesion of the lateral femoral condyle, right knee, T1 weighted MRI image, coronal view. **(d)** OCD lesion of the lateral femoral condyle, right knee, T2 weighted MRI image, sagittal view. Solid arrow: high signal at the interface between the fragment and the parent bone, indicates the presence of either granulation tissue or synovial fluid, and it is a bad prognostic sign of healing of the osteochondral lesion by conservative means. Dotted arrow: interruption of the continuity of the fragment's cartilage, a strong indication of the potential instability of the osteochondral fragment MRI ICRS type III.

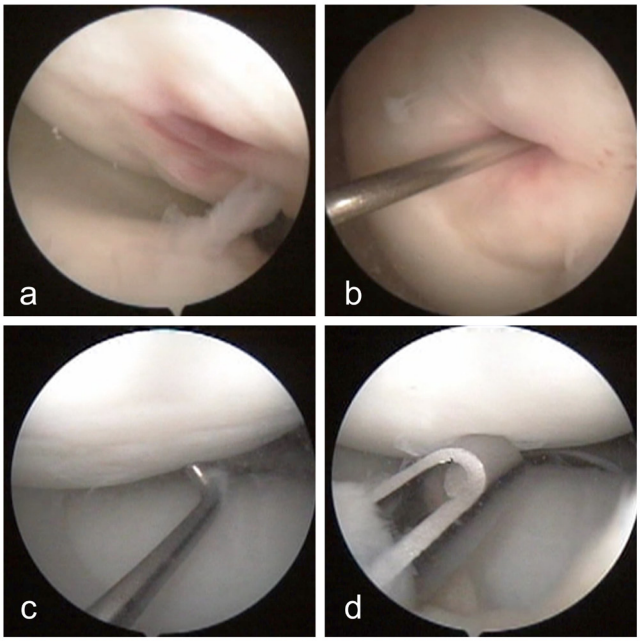

Figure 3. Arthroscopic evaluation of the OCD lesions.

(a) OCD lesion of the medial femoral condyle, left knee, **(b)** probing the OCD lesion of the medial femoral condyle, ICRS Stage III, **(c)** OCD lesion of the lateral femoral condyle, right knee, probing the OCD lesion ICRS Stage II, **(d)** Single-Shot Sheath in place, for chondral dart insertion.

Surgical technique

The procedures were performed arthroscopically with the patient under general anesthesia and using a thigh tourniquet. The anterolateral portal was used for the inspection of the M.F.C lesions, using a 4mm arthroscope, 30º oblique views (**figure 4 a**). For the instrumentation, necessary for the insertion of the chondral darts, the anteromedial portal was used to fix the M.F.C lesions (**figure 4 a**). By contrast, for the inspection of the L.F.C lesions, the anteromedial portal was used. Correspondingly, for the fixation of the L.F.C lesions, the anterolateral portal was used. A pilot hole within the osteochondral fragment to a depth of 20 mm was drilled with a drill pin through the Single Shot sheath (**figure 4 a**). A Chondral Dart 18 mm long was loaded into the end of the sheath (**figures 4 b, 5**). Once inserted into the sheath, a Single Shot Dart Inserter was used to deliver the dart into the pilot hole. With light taps on the inserter, confirmation was made that the Dart was seated, when the inserter contacts the back of the sheath, recessing the Dart 2 mm below the hyaline cartilage surface (**figure 4 c-f**)**.** To provide solid fixation of the osteochondral fragments, 3-5 chondral darts, 18 mm long, 1.3 mm diameter were inserted.

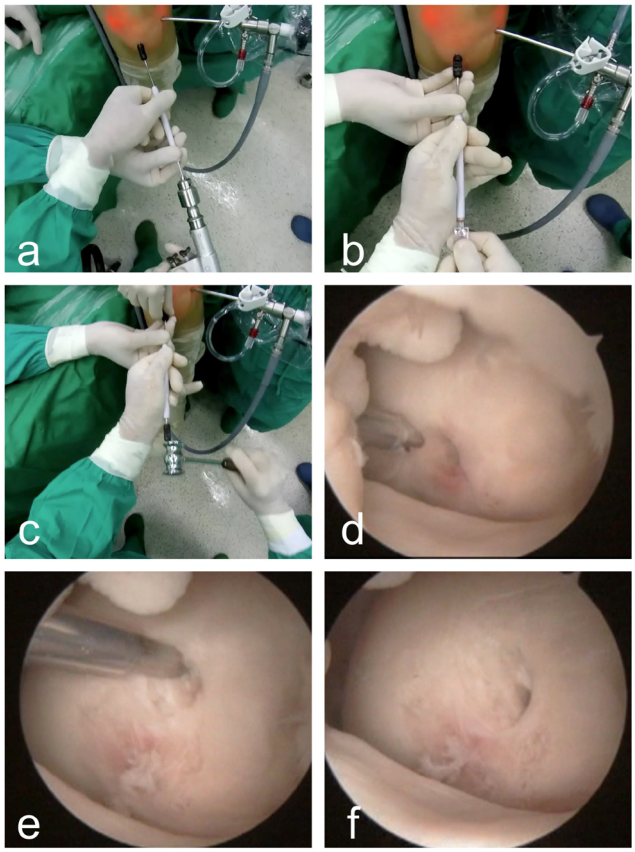

Figure 4. Arthroscopic fixation of the OCD lesion of the medial femoral condyle with chondral darts Surgical technique.

Anterolateral portal for the insertion of 4 mm arthroscope, 30º oblique views. Anteromedial portal for the instrumentation, to fix the M.F.C lesion with chondral darts. **(a)** A pilot hole within the osteochondral fragment to a depth of 20 mm is drilled with a drill pin through the Single Shot sheath. **(b)** A Chondral Dart 18 mm long is loaded into the end of the sheath. **(c)** Once inserted into the sheath, a Single Shot Dart Inserter is used to deliver the dart into the pilot hole, recessing the Dart 2 mm below the hyaline cartilage surface. With light taps on the inserter, confirmation that the Dart is seated is made when the inserter contacts the back of the sheath. **(d)** Arthroscopic view. Chondral dart in place, within the osteochondral fragment, recessing 2 mm below the hyaline cartilage surface. **(e)** Arthroscopic view. Third chondral dart in place. **(f)** Arthroscopic view. Final image. Fixation of the osteochondral fragment with four chondral darts.

Figure 5. Chondral Dart, 1.3 mm ×18 mm.

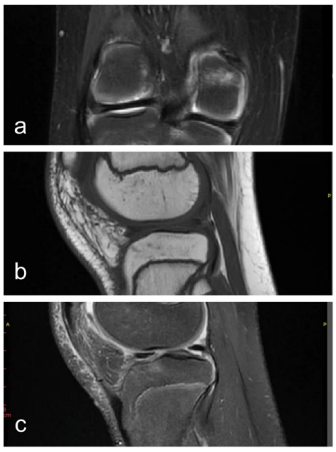

Figure 6. Postoperative MRI of the right knee, 18 months after the fixation of the L.F.C, OCD lesion with Chondral Darts. Complete healing of the OCD lesion.

(a) T2 weighted MRI image, coronal view, **(b)** T1 weighted MRI image, sagittal view, **(c)** T2 weighted MRI image, sagittal view.

Figure 7. Postoperative MRI of the left knee, 24 months after the fixation of the M.F.C, OCD lesion with Chondral Darts. Complete healing of the OCD lesion.

(a) T1 weighted MRI image, coronal view, **(b)** T1 weighted MRI image, sagittal view, **(c)** T2 weighted MRI image, coronal view, **(d)** view image, proximal slice. Patella is in a good position.

RESULTS

A total of thirty-one patients (n = 31) (32 knees, 7 right knees and 15 left) were included in the analysis. Of these patients, 19 (61.3%) were males and 12 (38.7%) were females (**table III).** From the 32 knees, the M.F.C was affected in 21 knees (65.6%), and the L.F.C in 11 knees (34.4%) (**table IV**). Nine knees (9 patients), sustained symptomatic stable OCD, detected by MRI (ICRS type II) (28.1%) and confirmed by arthroscopy (ICRS stage I) (28.1%). These nine knees stable OCDs, remained symptomatic despite the conservative treatment they had for 6 months (restraint of sports activities and immobilization of the knee for 6 weeks in a knee brace). From the remaining twenty-three OCDs knees (22 patients), 17 were MRI: ICRS type III (53.1%), and six were MRI: ICRS type IV (18.8%) (**table IV**). The Arthroscopic exploration revealed five knees: ICRS stage II (15.6%), and 18 knees ICRS stage III (56.3%) (**table IV**). The bioabsorbable chondral darts were used for the fixation of the thirty-two osteochondral fragments, to secure their stability and mainly to stimulate their healing**.** The mean patient age at the time of surgery was 12.64 ± 0.98 years (range 10-14 years) (**table III**). The average follow-up was 2.58 ± 0.71 years (range, 2-4) years (**table III**). No complications occurred. MRI obtained approximately after a mean of 20 months postoperatively showed complete healing of the osteochondral lesion (**figures 6, 7**). The mean preoperative IKDC score was 31.67 ± 8.36 (range, 23-45) points (**table V**). The mean postoperative IKDC score was 83.5 ± 1.52 (range, 81-86) points (**table V**). The 2-tailed p value < 0.001 was statistically significant with t = 39.33 and degrees of freedom 30 (**table V**).

Ethics

All procedures performed in this study involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

Table III. Gender*, Knee Side*, Age¥, Follow-up¥.

Gender		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	19	61.3	61.3	61.3
	Female	12	38.7	38.7	38.7
	Total	31	100.0	100.0	100.0

Age	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	31	10.00	14.00	12.6452	0.98483
Valid N	31				

Knee side		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Right	17	53.1	53.1	53.1
	Left	15	46.9	46.9	46.9
	Total	32	100.0	100.0	100.0

Follow-up	N	Minimum	Maximum	Mean	Std. Deviation
Follow	31	2.00	4.00	2.5806	0.71992
Valid N	31				

*Frequency, valid percent; ¥Minimum-Maximum, Mean.

Table IV. *Femoral Condyle (Medial lateral), *MRI (ICRS Classification System - OCD Evaluation), *arthroscopy (ICRS Classification System, OCD Evaluation).

Femoral condyle: medial lateral		Frequency	Percent	Valid percent	Cumulative percent
Valid	M.F.C	21	65.6	65.6	65.6
	L.F.C	11	34.4	34.4	34.4
	Total	32	100.0	100.0	100.0
MRI: OCD evaluation		**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid	ICRS II	9	28.1	28.1	28.1
	ICRS III	17	53.1	53.1	53.1
	ICRS IV	6	18.8	18.8	18.8
	Total	32	100.0	100.0	100.0
ARTHROSCOPY: OCD EVALUATION		**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid	ICRS I	9	28.1	28.1	28.1
	ICRS II	5	15.6	15.6	15.6
	ICRS III	18	56.3	56.3	56.3
	Total	32	100.0	100.0	100.0

*Frequency, valid percent.

Table V. IKDC Preoperative and Postoperative Score.

Paired Samples Statistics		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	IKDC POSTOP.	83.5806	31	1.52259	0.27347
	IKDC PREOP.	31.6774	31	8.36017	1.50153

Paired Samples Test		Paired Differences					t	df	Sig.(2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	IKDC POST - IKDC_PR	51.90323	7.23581	1.29959	49.24911	54.55734	39.938	30	0.000

2-tailed P-value.

DISCUSSION

The early identification of the OCD allows the initiation of appropriate treatment that will prevent the aggravation of this pathological process and can lead to the healing of the localized, osteochondral lesion. MRI is useful for the assessment of the fragment's articular cartilage continuity, and the evaluation of the size and viability of its subchondral bone. The presence, in the T2 Weighted MRI image, of a high signal at the interface between the fragment and the parent bone, indicates the presence of either granulation tissue or synovial fluid, and it is additional evidence of possible instability of the OCD lesion. In addition, the presence of either granulation tissue or synovial fluid displays the weakness of healing of the osteochondral lesion by conservative means. Arthroscopic exploration is the next necessary step for the confirmation of an unstable OCD. The OCDs knees with bad prognostic evolution (MRI: ICRS type III and IV), (Arthroscopy: ICRS stage II and III) need arthroscopic fixation. Arthroscopic exploration and treatment are also necessary in the cases of symptomatic, stable OCDs knees in MRI evaluation (MRI: ICRS type I, and II), after the failure of six months of conservative treatment, consisting of restraint of sports activities and initial immobilization of the knee for 6 weeks in a knee brace. Several surgical procedures have previously been described for the fixation of symptomatic unstable OCD lesions. None of these surgical procedures have been globally successful. For many OCD lesions, a second operative intervention is often required. In 1957, Smillie (9) reported a technique that used metallic nails. Since then, many fixation implants have been evaluated (staples, screws with or without a head, and more recently, bio-absorbable nails (10) and screws) (11). Bioabsorbable implants are an alternative to metal and provide stable fixation (12-20). Bio-absorbable materials have gained preference in North America (21). The bioabsorbable Chondral Dart implant has a double-reversed-barbed design to facilitate superior fixation and compression of the osteochondral fragment. The 18 mm long, 1.3 mm diameter Chondral Dart implant provides secure fixation of the osteochondral fragment. Their important advantage is that no further procedure is required to remove the implant. Until now, no complications have been reported and observed from their use. For large OCD lesions, the Bio-Compression Screw may be used to fixate OCD lesions securely while eliminating the challenges of metal screw removal.

With regard to limitations on the use of bioabsorbable materials, in the International Literature, a case of systemic allergic reaction has been reported after the use of a multi-L-lactic acid biodegradable interference screw for anterior cruciate ligament reconstruction with a bone-patellar tendon-bone graft (22). There is also a case report of local fibroxanthoma occurrence after ACL reconstruction using a biodegradable interference screw (23). Finally, it should be emphasized that their use for the stabilization of purely focal chondral lesions is useless because articular cartilage does not contain vascular, nervous and lymphatic tissue and chondrocytes hardly participate in the healing or repair process of chondral tissue (24). Osteochondral autograft transplantation is a one stage procedure and repairs the lesion with hyaline cartilage. But its limitation is the lack of donor site availability.

In this study, the data analysis of the fixation results of the unstable OCD lesions with absorbable chondral darts, using the IKDC evaluation system, was similar to that of other researchers in the literature who used also absorbable chondral darts as fixation materials, and the IKDC evaluation system (10, 11, 25-27).

CONCLUSIONS

Surgical treatment to promote healing is recommended for stable (immobile) lesions that did not respond to six months of conservative treatment and for unstable (mobile) lesions.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

PM: surgical technique, study design, performed measurements, manuscript preparation, photo editing, video editing, statistical analysis. OM: study design, manuscript preparation, photo editing, video editing, statistical analysis.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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