A Radiographic Healing Classification for Osteochondritis Dissecans of the Knee Provides Good Interobserver Reliability

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Background: Recent studies have examined radiographic factors associated with healing of osteochondritis dissecans (OCD) lesions of the knee. However, there is still no gold standard in determining the healing status of an OCD lesion.

Purpose: We examined temporally associated patterns of healing to (1) evaluate the practicality of a classification system and (2) elucidate any associations between healing pattern and patient age, sex, lesion location, treatment type, and physeal patency.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: We retrospectively screened 489 patients from 2006 to 2010 for a total of 41 consecutive knee OCD lesions that met inclusion criteria, including at least 3 consecutive radiographic series (mean patient age, 12.8 years; range, 7.8-17.1 years; mean follow-up, 75.1 weeks). Radiographs were arranged in sequential order for ratings by 2 orthopaedic sports medicine specialists. Healing patterns were rated as *boundary resolution*, *increasing radiodensity of progeny fragment*, *combined*, or *not applicable*. Repeat ratings were conducted 3 weeks later.

Results: Patients were most commonly adolescent males aged 13 to 17 years, with a medial femoral condyle lesion that was treated operatively. Interobserver reliability of the healing classification was good (intraclass correlation coefficient, 0.67; 95% CI, 0.55-0.79). Boundary and radiodensity healing was observed for all ages, sexes, lesion locations, treatment types, and physeal patency states.

Conclusion: This study evaluated a valuable radiographic paradigm—boundary resolution, increasing radiodensity of progeny fragment, or combined—for assessment of OCD lesion healing. The proposed system of healing classification demonstrated good inter- and intraobserver reliability. Healing patterns were not significantly associated with any particular age, sex, lesion location, treatment type, or physeal patency status. The development of a classification system for knee OCD may eventually improve clinical assessment and management of OCD lesions.

Keywords: osteochondritis dissecans; healing classification; reliability; cartilage

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Osteochondritis dissecans (OCD) is commonly described as an acquired lesion of subchondral bone with potential for secondary alteration of articular cartilage.[6,11,13] Various authors have expressed the view that OCD lesions of the knee are becoming increasingly common in children and adolescents.[11] Although the etiology of OCD continues to be disputed, with discussions suggesting ischemia and genetic predisposition as contributors,[15] numerous authors have proposed repetitive microtrauma as an underlying mechanism; as such, it is possible that the rising incidence may be due in part to increased participation in sports at increasingly younger ages, especially for males.[3-5,11] Fortunately, the potential for healing is notable for skeletally immature individuals, with some authors reporting resolution in as many as two-thirds of patients with bracing and activity modification alone.[14,18]

Despite extensive investigation, a lack of consensus exists concerning the definition of "healing" or even how radiographic findings may correlate to healing.[7] Healing may also be defined by clinical outcomes, such as resolution of symptoms, as opposed to any particular finding on image

studies.[18] However, pathology has been correlated with particular markers on imaging, such as presence of a perilesional sclerotic ring from failure of reparative neovascularization, which leads to loosening of a progeny fragment from the parent bone.[8,13] Various studies have provided illustrations of a healing lesion or have used arbitrary cutoffs for radiographic healing as a study outcome, but minimal consistency exists among authors.[1,10] Recently, however, Wall et al[16,17] and the Research in Osteochondritis of the Knee (ROCK) Study Group have presented substantial work revealing high inter- and intrarater reliability on overall healing and various radiographic parameters and characteristics of each lesion. This work may lead to a consensus on which factors indicate that an OCD lesion of the knee has undergone healing.

Accordingly, a study involving the use of plain radiographs remains particularly relevant. Radiographs are the standard imaging modality of choice during the follow-up period, as findings of instability on magnetic resonance imaging correlate poorly with findings during arthroscopy, calling into question the reliability of this imaging modality for this pathology.[9] The goals of the current study were primarily to evaluate the practicality of a radiographic classification system for evaluating healing of the OCD lesion with plain radiographs and, secondarily, to elucidate any associations between these healing patterns and patient age, sex, lesion location, treatment type, or physeal patency.

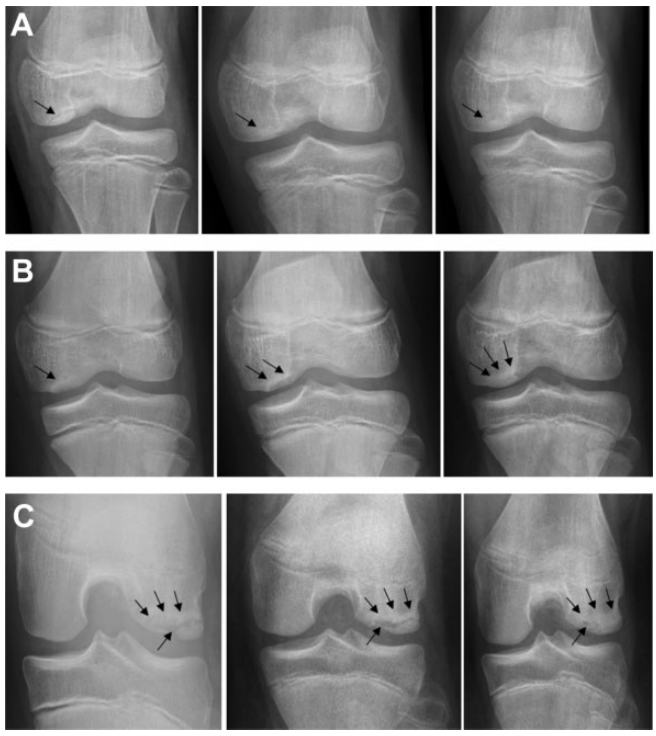

Figure 1. Osteochondritis dissecans (OCD) healing pattern types from left to right: (A) resolution of the boundary (distinct to indistinct) between progeny fragment and parent bone, (B) increasing radiodensity of progeny fragment from radiolucent to similar radiodensity as parent bone, and (C) combined features of boundary resolution and increasing radiodensity patterns. Arrows indicate areas of healing OCD lesion. Raters were presented with image series in the same format for classification into 1 of the following healing categories, respectively: boundary resolution, increasing radiodensity, and combined.

METHODS

After approval from an institutional review board, a retrospective analysis was conducted on consecutive patients who were treated for OCD lesions of the knee at a level 1 tertiary care pediatric hospital. Patients were identified by hospital database search and were included if they were <18 years of age, had at least 3 consecutive radiographic image series (including lateral or notch view), and had an OCD lesion of the knee. Although some patients had notch views obtained only after their initial clinical visits, likely for the purpose of follow-up of lesion appearance, all available views for each patient were compiled and provided to the physician rater in the form of blinded PowerPoint slides. In the absence of at least 2 orthogonal radiograph views at each clinical encounter, the patient was excluded from the study. Lesions in patients with bilateral pathology were considered distinct entries. Patients were excluded if they did not meet age criteria or if they lacked sufficient imaging as described. Data collected included age, sex, lesion location, and treatment type, further divided into 2 groups: those receiving operative care within 6 months of diagnosis and those receiving nonoperative treatment for >6 months from diagnosis. A formal informed consent process was not required by the institutional review board, given the retrospective nature of the study.

Radiographic images were collected and arranged in sequential order for rating. Two fellowship-trained orthopaedic sports medicine specialists classified the consecutive images according to lesion location, healing pattern, and physeal patency while blinded to all demographic and treatment details except time from initial presentation. For each included patient, healing patterns were rated as 1 of the following: resolution of the boundary between progeny fragment and parent bone (ie, from distinct boundary to indistinct boundary), increasing radiodensity of the progeny fragment (ie, from radiolucent to the same radiodensity as the parent bone), combined (features of boundary resolution and increasing radiodensity patterns), or not applicable. Results were collected in the form of 1 categorical response from the stated options. Figure 1 presents representative lesions and healing patterns. Physeal patency was rated by examination of the radiograph at initial patient presentation regardless of physeal patency at the time of final follow-up. Both physicians repeated the blinded rating process 3 weeks after the initial reading.

Statistical analysis included primary outcomes of intraclass correlation coefficient (ICC) for inter- and intrarater reliability, overall percentage agreement, and demographic trends. For interpretation of the resulting ICCs, standards for the magnitude of the reliability coefficient were obtained from Altman[2] (Table 1). In addition to these

TABLE 1
Altman[2] Standard for Reliability Coefficient Magnitude

Coefficient Value	Quality
0.0-0.2	Poor
0.2-0.4	Fair
0.4-0.6	Moderate
0.6-0.8	Good
0.8-1.0	Very good

measures, percentage agreement and the Randolph free-marginal multirater kappa were calculated for the agreement between readers on whether "boundary" or "radiodensity" healing patterns were exhibited in a lesion, since a rating of "combined" would qualify if both were present. The Fisher exact test was employed for the secondary outcome examining associations between healing types and age, sex, lesion location, operative versus nonoperative treatment, and physeal patency. For the latter analysis, lesions were assigned a single healing type and physeal status according to combined ratings; this was determined by considering all 4 reader measurements and assigning by majority. In the event of an even discrepancy between readers, a tiebreaker rating from the senior attending was used. Calculations were conducted with SPSS for Windows (v 20; IBM).

RESULTS

Of 489 patients screened, 41 consecutive knee OCD lesions were evaluated, representing all cases that met inclusion criteria for a single surgeon from 2006 to 2010. The mean follow-up period was 75.1 weeks (range, 14-276); the mean time between radiograph studies was 22 weeks. The mean patient age was 12.8 years (SD, 2.1; range, 7.8-17.1), and the sex distribution was 35 males and 6 females. Patients were most commonly male adolescents between the ages of 13 and 17, with open physes, receiving operative treatment, with a medial femoral condyle lesion.

All healing types, with the exception of "not applicable," were observed in patients across both sexes and all age groups, lesion locations, treatment types, and physeal patency status. The percentage agreement across all healing ratings combined for both attending physician raters was 0.78. The inter- and intraobserver reliabilities (ICCs) of the proposed healing classification were 0.67 (95% CI, 0.55-0.79). These are considered "good" by the Altman[2] standard. For the physeal patency rating, the interobserver reliability was 0.87 (95% CI, 0.81-0.92), and the intraobserver reliability was 0.82 (95% CI, 0.75-0.89), which are both considered "very good" by the Altman standard (Table 2).

Table 3 delineates results for percentage agreement and the Randolph free-marginal multirater kappa between raters according to agreement concerning presence/absence of individual healing types. Conduction of Fisher exact test with the combined ratings revealed no statistically significant associations between any of the healing types and patient age, sex, lesion location, operative versus nonoperative treatment, or physeal patency.

TABLE 2
Results for Combined Ratings of Healing Classification and Physeal Patency[a]

	Interobserver Reliability			Intraobserver Reliability		
	ICC	95% CI	Quality	ICC	95% CI	Quality
Healing pattern	0.67	0.55-0.79	Good	0.67	0.55-0.79	Good
Physis	0.87	0.81-0.92	Very good	0.82	0.75-0.89	Very good

[a]ICC, intraclass correlation coefficient.

TABLE 3
Interobserver Percentage Agreement and Free-Marginal Kappa by Presence/Absence of Healing Type

	Boundary		Radiodensity	
Rating	Agreement, %	Component κ	Agreement, %	Component κ
First	0.78	0.56	0.98	0.95
Second	0.80	0.61	0.93	0.85

DISCUSSION

The study results suggest the utility of the proposed radiographic classification system for healing of OCD lesions of the knee, as it provides good inter- and intraobserver reliability. As demonstrated by multiple authors, there is a lack of consensus on what "healing" entails in OCD lesions, whether clinically or radiographically.[1,7,9,10,12,18] Indeed, Parikh et al[12] recently examined the reliability the of determining healing on radiographs and found that physicians did not consistently agree on the healing status of OCD lesions. Given the aforementioned state of the literature concerning classification discrepancies and inconsistencies in the use of imaging to determine healing status, the primary aim of this study was to examine the feasibility of a framework with which to approach the progression of lesion healing.

As of the current study, the majority of previous studies focused on individual prognostic factors for healing potential or findings on imaging that indicate lesion instability.[4,7,13,16] The need for interprovider agreement on a standardized definition of lesion healing has been established in the literature.[7,12,15]

In a study of 47 knees that examined OCD lesion reossification on serial plain films over 6 months of nonoperative treatment, Wall et al[18] found that smaller-sized lesions were more likely to progress to healing. They also found that patient age, lesion sidedness (left knee vs right), and lesion location (lateral vs medial femoral condyle) did not play a role in predicting healing potential. Similarly, in a study of 59 OCD lesions, Edmonds et al[6] found a significant

difference in the rate of healing between small and large lesions. These findings support those of the current investigation, which failed to establish any statistically significant correlation between the aforementioned factors and any particular healing pattern, with the exception of lesion size (not examined in the current study).

The most significant recent investigations concerning this topic were carried out by Wall et al and the ROCK Study Group.[16,17] In a multicenter study, they found excellent inter- and intrarater reliability using a continuous scale of radiographic images, as well as excellent reliability for what were termed the 5 "subfeatures" involved in healing on radiographs (boundary, sclerosis, size, shape, and ossification). Of note, the ordinal rating of overall healing had significantly lower inter- and intrarater reliabilities of 0.61 and 0.68, respectively.[16] The current study assigned similar radiographic features of boundary and radiodensity/sclerosis to group healing patterns and translated them into a categorical rating system, resulting in inter- and intraobserver ICCs of 0.67—findings similar to those of the ordinal trial findings. In an earlier study by the same group, the radiographic parameter of progeny bone boundary had greater interrater reliability than that of progeny bone center radiodensity (0.62 vs 0.52).[17]

This study had multiple limitations, the most important likely being the small size of the cohort and the relatively few number of physician raters. Applicability of the proposed categorization to a variety of clinical settings is limited, given that both raters were sports fellowship–trained orthopaedic surgeons. Inclusion of professionals from various disciplines would enhance the strength of the findings. A larger cohort may elucidate associations between healing types and factors such as age, treatment type, and so on, as the data would be more likely to approach statistical significance. Additionally, our results lack correlation with clinical outcome measures; this analysis was outside the scope of the current investigation. A future study combining clinical outcome data with the proposed radiographic healing types could augment OCD treatment protocols. However, these limitations did not hinder the course of the study nor the conclusions drawn, as the data revealed that the employed system still had substantial reliability despite these factors.

We recognize that this study provides mostly a preliminary, yet important, framework on which future studies can directly build. Correlation of healing patterns with pathological specimens to determine whether these lesions are histologically distinct would prove extremely valuable. Subsequently, if lesions are conceptualized as unique entities, investigations concerning how treatment might be tailored to the patient would be appropriate. Additionally, correlation of healing pattern to clinical outcomes such as pain scores, time to clinical recovery, or return to pretreatment levels of activity would be necessary, perhaps in a prospective analysis.

This study builds on the previous body of work concerning radiographic factors involved in assessment of OCD lesion healing. The employed system of healing classification on radiographs (boundary resolution, increasing radiodensity of progeny fragment, and combined) demonstrated good inter- and intraobserver reliability. Healing patterns were not significantly associated with any particular age, sex, lesion location, treatment type, or physeal patency status. The current study presents an important framework on which future correlations with tissue pathology and clinical outcomes may be based.

REFERENCES

1. Adachi N, Deie M, Nakamae A, Ishikawa M, Motoyama M, Ochi M. Functional and radiographic outcome of stable juvenile osteochondritis dissecans of the knee treated with retroarticular drilling without bone grafting. *Arthroscopy*. 2009;25(2):145-152.
2. Altman D. *Practical Statistics for Medical Research*. London, England: Chapman & Hall; 1991.
3. Anderson AF, Richards DB, Pagnani MJ, Hovis WD. Antegrade drilling for osteochondritis dissecans of the knee. *Arthroscopy*. 1997;13(3): 319-324.
4. Boughanem J, Riaz R, Patel RM, Sarwark JF. Functional and radiographic outcomes of juvenile osteochondritis dissecans of the knee treated with extra-articular retrograde drilling. *Am J Sports Med*. 2011;39(10):2212-2217.
5. Cahill BR. Osteochondritis dissecans of the knee: treatment of juvenile and adult forms. *J Am Acad Orthop Surg*. 1995;3(4):237-247.
6. Edmonds EW, Albright J, Bastrom T, Chambers HG. Outcomes of extra-articular, intra-epiphyseal drilling for osteochondritis dissecans of the knee. *J Pediatr Orthop*. 2010;30(8):870-878.
7. Edmonds EW, Polousky J. A review of knowledge in osteochondritis dissecans: 123 years of minimal evolution from Konig to the ROCK study group. *Clin Orthop Relat Res*. 2013;471(4):1118-1126.
8. Flynn JM, Kocher MS, Ganley TJ. Osteochondritis dissecans of the knee. *J Pediatr Orthop*. 2004;24(4):434-443.
9. Heywood CS, Benke MT, Brindle K, Fine KM. Correlation of magnetic resonance imaging to arthroscopic findings of stability in juvenile osteochondritis dissecans. *Arthroscopy*. 2011;27(2):194-199.
10. Hughes JA, Cook JV, Churchill MA, Warren ME. Juvenile osteochondritis dissecans: a 5-year review of the natural history using clinical and MRI evaluation. *Pediatr Radiol*. 2003;33(6):410-417.
11. Kocher MS, Tucker R, Ganley TJ, Flynn JM. Management of osteochondritis dissecans of the knee: current concepts review. *Am J Sports Med*. 2006;34(7):1181-1191.
12. Parikh SN, Allen M, Wall EJ, et al. The reliability to determine "healing" in osteochondritis dissecans from radiographic assessment. *J Pediatr Orthop*. 2012;32(6):e35-e39.
13. Ramirez A, Abril JC, Chaparro M. Juvenile osteochondritis dissecans of the knee: perifocal sclerotic rim as a prognostic factor of healing. *J Pediatr Orthop*. 2010;30(2):180-185.
14. Seidenstein H. Osteochondritis dissecans of the knee; spontaneous healing in children. *Bull Hosp Joint Dis*. 1957;18(2):123-134.
15. Shea KG, Jacobs JC Jr, Carey JL, Anderson AF, Oxford JT. Osteochondritis dissecans knee histology studies have variable findings and theories of etiology. *Clin Orthop Relat Res*. 2013;471(4): 1127-1136.
16. Wall EJ, Milewski MD, Carey JL, et al; Research in Osteochondritis of the Knee (ROCK) Group. The reliability of assessing radiographic healing of osteochondritis dissecans of the knee. *Am J Sports Med*. 2017;45(6):1370-1375.
17. Wall EJ, Polousky JD, Shea KG, et al; Research in Osteochondritis Dissecans of the Knee (ROCK) Study Group. Novel radiographic feature classification of knee osteochondritis dissecans: a multicenter reliability study. *Am J Sports Med*. 2015;43(2):303-309.
18. Wall EJ, Vourazeris J, Myer GD, et al. The healing potential of stable juvenile osteochondritis dissecans knee lesions. *J Bone Joint Surg Am*. 2008;90(12):2655-2664.