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Limited evidence that the presence of a bone bruise alone affects the clinical outcome of surgically reconstructed anterior cruciate ligaments: a systematic review

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Abstract

Importance—Anterior cruciate ligament (ACL) injury can be a devastating injury that without surgery may lead to chronic instability. Although surgical reconstruction recreates the stabilising constraint of the native ACL, postoperative pain and subsequent arthrosis may follow.

Objectives—The primary objective of this systematic review is to determine whether the presence of a bone bruise following ACL rupture adversely affects the clinical outcomes following surgical reconstruction.

Evidence review—A standardised research protocol was used as outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. Studies included for review were those of high level of evidence (I or II) and had MRI data on the presence of bone bruise and clinical outcome measures in patients who underwent surgical reconstruction of the ACL after traumatic rupture. Articles were searched using PubMed/ Medline, Cochrane Library, CINAHL and EMBASE databases using a keyword search. Article references and conference proceedings were subsequently reviewed on identification of articles found via the keyword search. Non-English literature, animal and basic science studies, studies focused on the skeletally immature and low level of evidence (III, IV, V) were excluded. A quantitative analysis of the data retrieved was summarised.

Findings—Five studies met the inclusion criteria. Follow-up ranged from the time of surgical reconstruction to 165 months. Although a variety of clinical outcome measures were used across studies, bone bruise cohorts did not demonstrate clinically inferior outcome scores.

Conclusions and relevance—Although osteochondral injury is frequently identified following ACL injury, the presence of a bone bruise alone does not appear to significantly

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adversely affect the clinical outcome of surgically reconstructed ACLs. However, factors such as articular cartilage injury and alteration in joint loading may be important variables for further research.

Level of evidence—IV.

INTRODUCTION

The anterior cruciate ligament (ACL) is an important stabiliser of the knee and is commonly ruptured with an incidence rate between 36.9 and 60.9 per 100000 persons/year.¹ The use of MRI in confirming the diagnosis of ACL injury has also assisted in the understanding of concomitant injury. Mink *et al* were the first to describe bone marrow oedema with the use of MRI.² The hyperintense signal seen on fluid-weighted sequences, referred to as a ‘bone bruise,’ is observed in up to 80% of patients with ACL tears.^{3,4} Moreover, localisation of the bone bruise appears to be correlated with the mechanism of injury.⁵ Previous studies have highlighted the associated injuries to the articular cartilage, meniscus and adjacent subchondral bone,³ but precisely how the presence of a bone bruise affects prognosis is incompletely understood. Moreover, whether or not the presence of bone bruising adversely affects the outcome of surgical reconstruction remains to be determined. The purpose of this systematic review is to determine whether the presence of bone bruising adversely affects the outcome of surgery for ACL instability. The authors aim to determine the clinical influence of a bone bruise on surgically treated ACL rupture in skeletally mature individuals and determine the need for further research and collaborative studies in an effort to improve the treatment of ACL injury.

METHODS

This study was designed as a systematic review of the current literature. A standardised research protocol was used as outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines www.prisma-statement.org.⁶

Articles were searched using PubMed/Medline, Cochrane Library, CINAHL and EMBASE. In order to identify all possible salient articles efficiently, a university librarian experienced in comprehensive literature searches was utilised. The initial examination was completed in each of the above databases using the following keyword search, ‘(Anterior cruciate ligament OR ACL) AND (bone or osseous) AND (bruise OR contusion OR edema)’.

Inclusion criteria were articles with levels of evidence I or II, which included the evaluation of a bone bruise by MRI in the setting of ACL reconstruction (ACLR) surgery with reported clinical outcome measures. Only human studies written in the English language were included. Exclusion criteria were articles of low level of evidence (level III, IV, V), inability to determine the presence of a bone bruise, non-surgically treated ACL injury, articles without clinical outcome assessment, studies that included the skeletally immature, animal or basic science articles and languages other than English.

Articles not meeting inclusion criteria based on title (eg, non-English language, animal studies, review articles, case series, etc) were excluded. Two authors (BEW and WRD)

independently reviewed the remaining available abstracts, references and conference proceedings. Any discordance was resolved based on the opinion of a third author. Final inclusion required universal consensus among all authors. Data, study objectives, study design and outcomes, were extracted and imported into a standard spreadsheet software programme for analysis (Microsoft Excel 2009). CONSORT statement was used to assess the quality of the studies.⁷ Descriptive data will be analysed dependent on the included studies. Data comparison will be performed if possible.

RESULTS

The initial literature search retrieved a total of 743 articles. A total of 617 articles were excluded based on title. The abstracts of the remaining 126 articles were reviewed and five articles met the inclusion criteria (figure 1) Supplementary BBSR flow chart.

Of the five articles that met the inclusion criteria, one study was a cohort study that examined the outcomes in patients with and without bone bruise identified at baseline enrolment (initial evaluation).⁸ The remaining four articles were cohort studies that reported on the evolution of MRI findings in patients who sustained ACL injury.^{9–12} Of the studies that examined findings over time, one study included only patients that had a bone bruise and ACLR.³ The five included articles totalled 685 patients.^{8–12} Table 1 summarises the study populations and includes mean, SD and ranges when available. Table 2 lists the patient-reported outcomes from each study stratified by bone bruise status.

DISCUSSION

Although there is reasonable evidence that bone marrow oedema is commonly associated with ACL injury and generally resolves, few comparative studies have investigated the clinical significance of the finding. MRI has become a standard imaging modality for patients who have a suspected ACL injury. A frequent finding is low signal on T1-weighted sequences and high signal on fluid-weighted sequences involving the subchondral bone often found to involve the posterior portion of the lateral tibia and adjacent middle third of the lateral femoral condyle. This characteristic pattern has been hypothesised to occur from the anterior translation (subluxation) of the lateral tibia during injury. Mink and Deutsch first characterised this abnormality as a bone bruise.¹¹ They defined a bone bruise as 'a traumatically involved, geographic, and non-linear area of signal loss involving the subcortical bone' detected on T1-weighted sequences with corresponding increased signal on fluid-weighted sequences. Their initial study found that 72% of patients with complete ACL tears had an associated bone bruise identified by MRI.

Subsequently, Graf *et al* evaluated the MRI of patients with clinically diagnosed ACL injuries and found that 48% had evidence of a bone bruise.¹³ However, they noted that 71% of patients had a bone bruise if the MRI was performed within 6 weeks of injury and none of the patients who had MRIs later than 6 weeks following injury had evidence of a bone bruise, suggesting that lesions may resolve with time. More recently, fat suppression and short tau inversion recovery sequences have better characterised bone bruises associated with ACL injury.⁵

In a level I study, Hanypsiak *et al*/included 44 patients from an original cohort of 54 consecutive patients (82%) who underwent unilateral ACLR without multiligament involvement.¹¹ Thirty-six (82%) patients had a bone bruise on index MRI. At an average of 12.7 years, no patient was found to have a subsequent bone bruise on follow-up imaging (eg, all bone bruised resolved). IKDC scores were not found to be significantly different between groups that had a bone bruise or abnormal articular cartilage signal compared with those without bone lesion. Moreover, when stratified by bone bruise location, no association was found with subsequent adjacent articular cartilage injury, suggesting that other factors, such as meniscectomy, may be more important.¹⁴

Potter *et al*/reported on a level II cohort study. All patients in their cohort sustained chondral damage at the time of injury.¹² At 7–11 years' follow-up, there was increased risk of cartilage degeneration in compartments unaffected by the bone bruise. Empirically, the common subsequent medial compartment arthrosis and resolution of osteochondral injury that involves the lateral compartment at the time of injury is difficult to completely reconcile. This observation seems to suggest the possibility of biomechanical factors that are associated with weight bearing alteration following ACLR as well as possible histopathological or metabolic alterations.¹²

In a prospective multicentre database level II study, Dunn *et al*/had baseline data for 525 patients.⁸ The study aim was to determine if a bone bruise was associated with more knee symptoms and pain at the time of ACLR as well as what factors were associated with the presence of a bone bruise. The presence of a bone bruise was captured as a discrete variable and recorded by location (none, lateral compartment, other). Clinical outcome scores included: KOOS pain subscale, KOOS symptom subscale, SF-36 bodily pain subscale and Marx activity scale. Eighty per cent (419 patients) of the study sample was found to have a bone bruise. Significant risk factors associated with more knee pain and symptoms were found to be: higher body mass index, female gender, LCL injury and older age. Only a concomitant LCL injury was both a significant and clinically relevant predictor of more pain and symptoms after adjusting for demographic and mechanistic factors, meniscal and articular cartilage injury. The presence of a bone bruise was not found to be associated with worse pain, symptoms or activity. Moreover, younger age and not jumping at the time of injury were significantly associated with the presence of a bone bruise.

Costa-Paz *et al*/examined MRI findings in 21 patients with a bone bruise, who underwent ACLR. Mean follow-up was 34 months (range 24–64 months).⁹ The authors' qualified bone bruises by location and grade. Type I was defined as diffuse signal of the medullary component distant from the subjacent articular surface. Type II was defined as localised signal with contiguity of the subjacent articular surface. Type III lesions were bone bruises that disrupted or depressed the normal contour of the cortical surface. The authors identified a total of 29 lesions in 21 knees. IKDC scores were compared between groups whose bone bruise remained and those whose bone bruise resolved on follow-up MRI. At a mean of 34 months, only 6 of 21 (29%) patients had a bone bruise identified on follow-up MRI. Although raw scores were not reported, 93% of patients without a bone bruise identified on MRI at follow-up had a normal or near-normal knee and 83% of patients with a bone bruise had a normal or near-normal knee. The authors found that all of the type I lesions resolved

and one type II lesion was present on second MRI. However, all five type III lesions found at the time of index MRI were identified on follow-up imaging. There was no correlation among findings on follow-up MRI between physical examination and stability of the knee, or IKDC scores among patients regardless of whether or not a bone bruise was identified. Although the presence of a bone bruise did not correlate with future MRI findings or clinical outcomes, significant involvement of the subjacent articular cartilage may persist even after successful reconstruction, a finding with uncertain long-term clinical implications.

Finally, Filardo *et al* reviewed 134 knees with ACL tear and an MRI within 6 months of the injury.¹⁰ Bone marrow oedema was significantly inversely associated with the time from ACL injury and MRI. However, the size of the bone marrow oedema significantly correlated with a return to previous sport level. When compared with patients who did not have bone marrow oedema, patients with a bone marrow oedema had a lower mean Tegner score. Despite these point estimates, there was considerable overall and wide confidence intervals in both groups.

Although the presence of a bone bruise in and of itself does not appear to be a causal variable associated with poor clinical outcomes, there is evidence to suggest that concomitant articular cartilage injury may be an important associated factor after ACLR. Faber *et al* examined 23 patients with occult osteochondral lesion (bone bruise) who underwent ACLR.¹⁴ The authors found that at 6-year follow-up, a significant number of patients had evidence of cartilage thinning adjacent to the site of the initial osteochondral lesion (13/23 patients). Furthermore, 65% of the patients were found to have persistent marrow signal changes. However, the clinical outcomes (Mohtadi Outcome Measure) and arthrometry data failed to demonstrate a significant difference between patients who were found to have persistent marrow changes and cartilage thinning on MRI compared with those who did not. Because this study lacked a control group and did not control for repeat surgical procedures or associated injury, and a high attrition rate, it was not included in this systematic review. That said, it raises the awareness that the identification of bone marrow changes on MRI may be associated with occult changes in the articular cartilage. It stands to reason that because of bone healing capacity, bone bruise alone may be less likely to lead to irreversible joint changes and inferior clinical results. Similarly, the limited healing capacity of articular cartilage is nevertheless an important consideration. As the technological ability to assess histopathology of osteochondral tissue by non-invasive imaging (eg, MRI) improves, future research may help identify the subset of patients who are at risk for future joint damage.

This study has several limitations. Because the authors set out to address a specific clinical question, the effect is a narrowly focused review. This may obviate the ability to draw meaningful generalisable conclusions regarding the many factors related to ACLR. The limited number of articles is likely reflective of the lack of high-quality research specifically addressing bone bruise and ACLR. Moreover, due to the heterogeneity of previous research, a meta-analysis was not performed thus limiting the power of statistical analysis. Furthermore, the possibility of selection bias is unavoidable and as described above, there is some evidence that bone bruise may be a factor in the identification of adjacent osteochondral injury leading to an important clinical effect. Similarly, given the lack of

evidence to suggest that bone bruise alone adversely affects the outcome of ACLR, there is mounting evidence that ACLR is not protective against the subsequent development of joint arthrosis.⁷ Future research may focus on the qualification of osteochondral tissue and mechanical factors following ACL rupture in an effort to optimise outcomes.

Conclusion

Based on the studies included in this systematic review, there is no convincing evidence that bone bruise alone identified on index MRI adversely affects outcome of ACLR. However, further research is necessary to determine the impact of articular cartilage and other associated injury on long-term outcomes.

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What is already known?

- Bone bruise or occult osteochondral injury is observed on magnetic resonance imaging in up to 80% of patients following anterior cruciate ligament rupture.
- Whether or not the presence of bone bruising adversely affects the outcome of surgical reconstruction remains to be determined.

What are the new findings?

- Supporting data from high level of evidence that bone bruise identification following anterior cruciate ligament (ACL).
- There appears to be lower level of evidence that articular cartilage is highly sensitive to injury associated with ACL rupture and an association with adverse clinical outcome is currently lacking.
- Rupture and subsequent cartilage loss may occur independent of a bone bruise.
- Additional factors, such as cartilage and meniscus injury, associated with ACL rupture may play an important role in subsequent outcomes following surgical reconstruction independent of bone bruise.

Figure 1.
Search strategy flow chart. ACL, anterior cruciate ligament.

Table 1

Characteristics of the studies included in the systematic review

Study	Evidence level	Number of knees	Age (years)	% Male	BMI	Number knees with bone bruise	Number of knees without bone bruise
Hamypsiak <i>et al</i> ¹	I	54	39	70	26.8	43 (80%)	11 (20%)
		44 at follow-up				0 at follow-up	44 (100%) at follow-up
Potter <i>et al</i> ²	II	28	35.1±8.2	48.1	NR*	18 in LFC	–
						24 in LTP	
Dunn <i>et al</i> ⁸	II	525	26±11	58	25.9±5.6	419 (80%)	106 (20%)
Costa-Paz <i>et al</i> ⁹	II	21	31; range 20–58	71	NR	21 (100%) at the time of injury	0 at the time of injury
						6 (29%) at follow-up	15 (71%) at follow-up
Filardo <i>et al</i> ¹⁰	IV	67	29.7±9.2	80.6	24.2 (3.6)	40 (59.7%)	27 (40.3%)

* Not reported.

BMI, body mass index.

Table 2

Patient-reported outcomes stratified by bone bruise status

Study	No bone bruise [*]	With bone bruise [*]	Overall [*]
Marx activity score			
Dunn <i>et al</i> ⁸	9.6 (5.8)	12.3 (4.8)	11.7 (5.1)
KOOS pain			
Dunn <i>et al</i> ⁸	68 (20)	70 (19)	69 (19)
KOOS symptoms			
Dunn <i>et al</i> ⁸	65 (20)	63 (19)	64 (19)
SF-36 bodily pain			
Dunn <i>et al</i>	44.3 (8.9)	45.7 (10.2)	45.4 (10)
IKDC			
Hanypsiak <i>et al.</i> ^{11†}	70.6 (12.7)	70.3 (11.7)	70.0 (8.1)
Costa-Paz <i>et al.</i> ^{9‡}	14/15 (93%) – normal or near normal	5/6 (83%) – normal or near normal	19/21 (90%) – normal or near normal

^{*} Mean (SD).

[†] At mean follow-up of 34 months. Raw IKDC score not reported.

[‡] At follow-up.