

# THE CROSS BRACING PROTOCOL

## A NOVEL NON-SURGICAL INTERVENTION TO FACILITATE ACL HEALING

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### CAN A RUPTURED ACL HEAL WITHOUT SURGERY?

Irrespective of management with ACL reconstruction or exercise-based rehabilitation, the long-term prognosis for patients with ACL injury is poor. Around 50% of people develop knee osteoarthritis within 10 years of ACL injury. Only 55 per cent return to sport after injury, re-injury is common and the ACL-injured knee can negatively affect quality of life across the life span. Both treatment options are based on an assumption that the ACL has limited or no healing capacity.

A recent analysis of data from the KANON randomised controlled trial challenges this assumption<sup>1</sup>. This study found that at least 30% of people randomised to initial exercise-based rehabilitation had signs of ACL healing (continuous ACL fibres) on MRI 2 years after ACL injury.<sup>1</sup> This increased to 53% after excluding people who decided to have delayed ACL surgery after trialling exercise-based rehabilitation<sup>1</sup>.

People with signs of ACL healing on MRI reported better sports and recreational

function and better knee-related quality of life at 2 years, compared to those with no signs of healing on MRI<sup>1</sup>. Surprisingly, they also reported better outcomes than people managed with ACL reconstruction<sup>1</sup>. Participants and treating clinicians were not aware of the healing status of the ACL during the study, so this did not influence their perception of their knee function or quality of life.

This research suggests that ACL ruptures can heal without ACL surgery, and ACL healing may be key to better patient outcomes.

### A NON-SURGICAL BRACING PROTOCOL MAY FACILITATE ACL HEALING

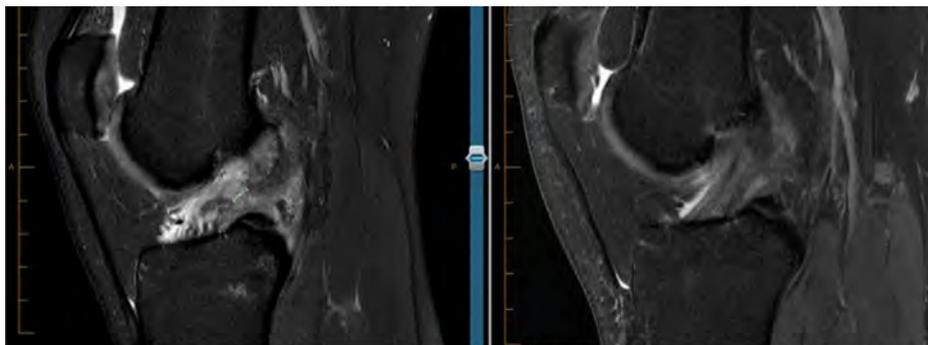
It was orthopaedic surgeon Dr Merv Cross's idea to brace a knee with acute ACL rupture in 90 degrees flexion. The ruptured remnants of the ACL are in closest proximity at  $\geq 90$  degrees of knee flexion and it was hypothesised that reducing the gap between the torn ends of the ACL and holding the knee in this position could encourage the formation of a bridge of

connective tissue between the torn ends of the ACL and subsequent ACL healing<sup>2</sup>.

The Cross Bracing Protocol involves applying a knee brace, ideally within the first 10 days post injury, and immobilizing the knee at 90 degrees flexion for the first 4 weeks, 24 hours per day<sup>2</sup>. This aligns with the orthopaedic principles of 'reduction' and 'immobilisation' of injured tissues. The brace is then adjusted at weekly increments to allow a progressive increase in range of motion<sup>2</sup>:

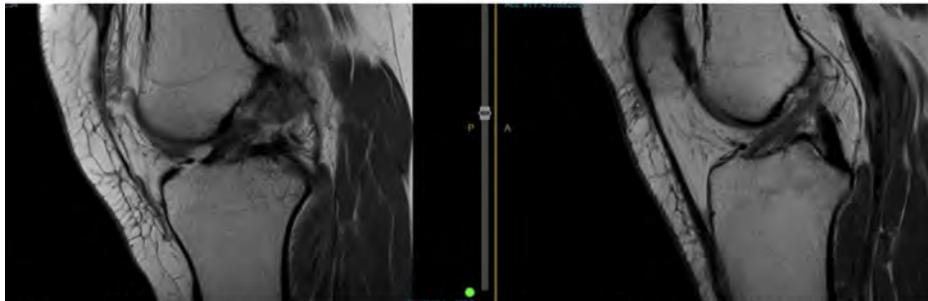
- Week 1-4: brace locked at 90 degrees flexion
- Week 5: 60 to 90 degrees flexion
- Week 6: 45 to 90 degrees flexion
- Week 7: 30 degrees to full flexion
- Week 8: 20 degrees to full flexion
- Week 9: 10 degrees to full flexion
- Week 10-11: unrestricted knee flexion/extension in brace
- Week 12: brace is removed

The patient ambulates non weight bearing for the initial 6-8 weeks but weight bearing is encouraged during rehabilitation exercises and ambulation



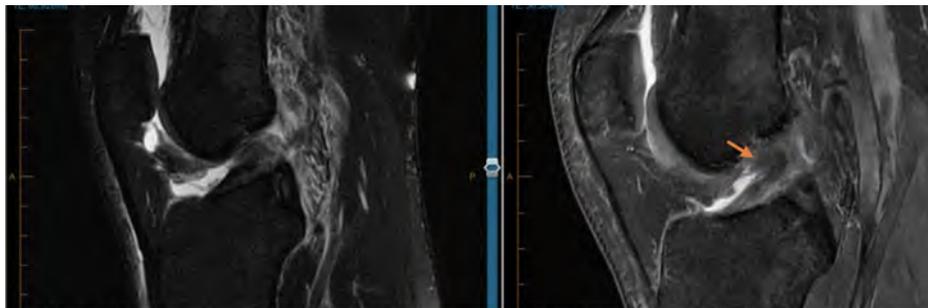
Baseline MRI: acute rupture

3-month MRI: continuous thickened ACL



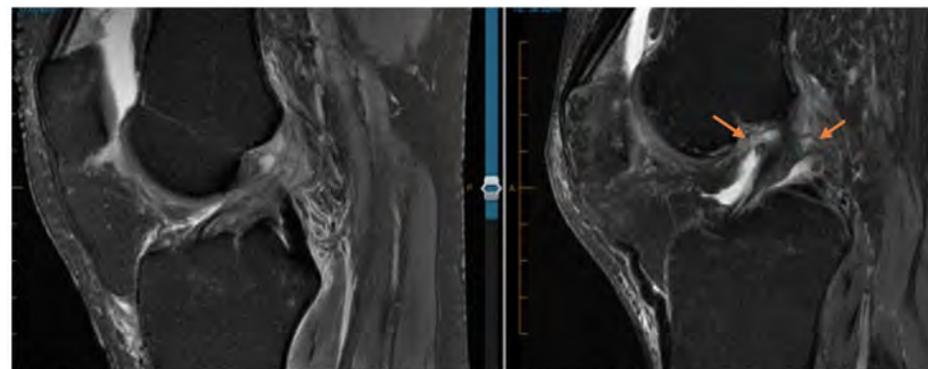
Baseline MRI: acute rupture

3-month MRI: continuous but thinned ACL



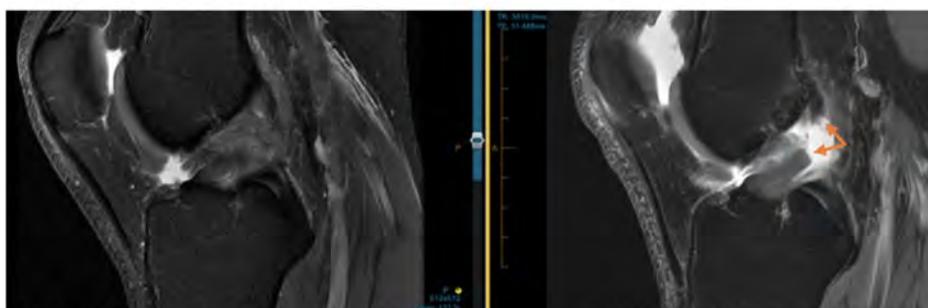
Baseline MRI: acute rupture

3-month MRI: attachment to the LW



Baseline MRI: acute rupture

3-month MRI: attachment to the LWP



Baseline MRI: acute rupture

3-month MRI: non-heal

**Figure 1:** MRI images of five patients, presenting the acute ACL rupture on MRI and examples of different ACL structures on 3-month MRI. ACL, anterior cruciate ligament; LW, lateral wall; LWP, lateral wall and PCL; MRI, magnetic resonance imaging.

as soon as the brace range of motion allows<sup>2</sup>. Knee bracing is combined with physiotherapist-supervised rehabilitation<sup>2</sup>. The detailed protocol, including medical and physiotherapy management, has been published open access in the British Journal of Sports Medicine<sup>2</sup>.

#### CLINICAL OUTCOMES FOLLOWING MANAGEMENT WITH THE CROSS BRACING PROTOCOL

We analysed outcomes from the first 80 patients managed with the Cross Bracing Protocol and found that 90 per cent had signs of ACL healing on 3-month MRI, using the same criteria used in the KANON trial (see MRI grading criteria in Figure 2). An example of different healing outcomes, as seen on MRI after management with the Cross Bracing Protocol, is shown in Figure 1.

#### DEFINING ACL HEALING ON MRI

To evaluate signs of ACL healing on MRI after ACL rupture, we used the Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS) MRI grading system<sup>3</sup> (Figure 2).

#### MORE ACL HEALING WAS ASSOCIATED WITH BETTER CLINICAL OUTCOMES

Our study of the first 80 people managed with the Cross Bracing Protocol found that on 12-week MRI, 50% of people had an ACLOAS Grade 1, 40% had an ACLOAS Grade 2 and 10% had a ACLOAS Grade 3<sup>2</sup>. Six out of eight ACLs with no signs of healing (ACLOAS Grade 3), had attached to the lateral wall and/or posterior cruciate ligament, observed on 3-month MRI<sup>2</sup>.

People with more healing on 3 month MRI (ACLOAS Grade 1), reported better 12-month outcomes, including return to sport (92 per cent returned to sport), knee laxity (100 per cent had a normal three-month Lachman test), knee function (the median Lysholm Knee Scoring Scale score was 98 out of a possible 100 points) and quality of life (the median Anterior Cruciate Ligament Quality of Life Questionnaire score was 89 out of 100) compared to people with an ACLOAS grade 2 or 3 at 3 months<sup>2</sup>.

## FIGURE 2

### ACLOAS MRI Grading

0 = Normal ligament with hypointense signal and regular thickness and continuity.

1 = Thickened ligament and/or high intraligamentous signal with normal course and continuity.

2 = Thinned or elongated but continuous ligament.

3 = Absent ligament or complete discontinuity.

**Figure 2:** Item from the Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS) MRI grading system used to evaluate signs of ACL healing (ACL continuity and appearance).

#### REHABILITATION EXERCISES FOR PEOPLE UNDERTAKING THE CROSS BRACING PROTOCOL

Goal-oriented, physiotherapist-supervised rehabilitation was performed whilst the brace is worn, and for 9 months following brace removal<sup>2</sup>. Although some patients feel capable of returning to sport before 12-months post-injury, we recommend delaying return to sports until 12-months post-injury to allow sufficient time for tissue remodelling (the final phase of ligament healing).

Whilst the knee is immobilised at 90 degrees flexion (week 1-4), rehabilitation aims include minimising local and global muscle atrophy, controlling swelling and pain, and DVT risk mitigation strategies<sup>2</sup>. Specific rehabilitation exercises performed during the first 4 weeks include<sup>2</sup>:

- Quadriceps and hamstring co-contractions
- Calf Theraband plantarflexion
- Hip abduction and extension
- Contralateral limb: single leg press, leg extension, hamstring curls, calf raise, glute bridge, core activation
- Upper body strengthening, ski ergometer, grinder

These exercises are progressed as the range of motion allowed in the brace increases at weekly increments. In week 7, people continue to progress wall squats/holds (week 7 = 45°, week 8 = 30°), body weight squats within brace limits, and

gait retraining<sup>2</sup>. By week 9, the aims of rehabilitation include increasing knee range of motion, increasing lower limb strength, and improving proprioception.<sup>2</sup> Typical rehabilitation exercises performed at 9 weeks include<sup>2</sup>:

- Knee range of motion exercises
- Pilates reformer/ leg press
- Body weight squats
- Bridges - hamstring and gluteal
- Crab walks/ monster walks
- Calf raises
- Static balance exercises
- Exercise bike if able to achieve over 100° flexion.
- Upper body strengthening, grinder

By week 10, the patient is wearing an unrestricted knee brace (full range of motion allowed in the brace), and has typically commenced single-leg leg press, use of a hamstring curl machine, and use of a standing/seated calf raise machine<sup>2</sup>.

After 12 weeks the brace is removed and rehabilitation progresses in difficulty, and includes a progressive, criteria-driven, return to running, agility exercises, hopping, training and sport<sup>2</sup>.

#### ADVERSE EVENTS

Of the first 80 patients managed with the Cross Bracing Protocol, 11 (14%) re-injured their ACL at a range of 5 to 18 months post bracing<sup>2</sup>. Four of the eleven (36%) had an ACLOAS Grade 1 on 3-month MRI. These injuries occurred during high-speed

skiing/cycling accidents or were rugby or Australian football (AFL) contact injuries<sup>2</sup>. The remaining 7 participants who re-injured their ACL had an ACLOAS grade 2 on 3 months MRI<sup>2</sup>. Nine of the eleven patients who experienced a second ACL injury elected to undergo ACL reconstruction<sup>2</sup>.

Only 2 of the 80 participants required knee surgery for reasons other than the ACL injury; one patient for cyclops lesion debridement and one for partial meniscectomy. Interestingly, of the 39 people who had concomitant meniscal injury at baseline, only 1 person remained symptomatic following brace removal<sup>2</sup>.

Two patients were diagnosed with a deep vein thrombosis (DVT) in the second week of the Cross Bracing Protocol<sup>2</sup>. Both patients were successfully managed with anticoagulation therapy. Risk mitigation strategies including DVT prophylaxis medication were employed following these events for all patients thereafter, with no further DVT events<sup>2</sup>.

#### ONGOING RESEARCH TO INFORM CLINICAL PRACTICE

More than 500 patients have now been managed with the Cross Bracing Protocol in clinical practice. We are now analysing data from a larger sample to try to understand who is more likely to experience a successful healing outcome following management with the Cross Bracing Protocol. In clinical practice, we have learnt overtime that signs of ACL rupture as observed on baseline MRI, may relate to the likelihood of achieving a successful healing outcome with the Cross Bracing Protocol. Variables that we are exploring include partial femoral avulsion of the ACL, displacement of distal ACL fibres outside of the intercondylar notch, and the gap distance between the torn ends of the ACL. We are also developing new MRI grading criteria to assess the characteristics of acute ACL rupture that relate to healing, and to better assess ACL healing on MRI as it relates to knee function.

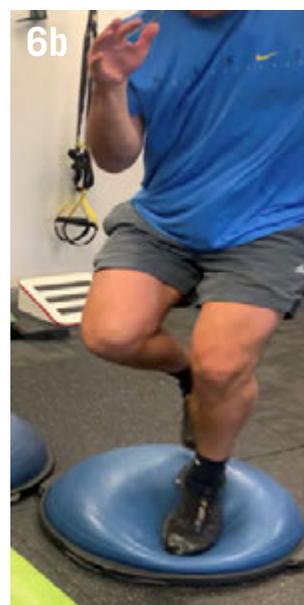
We have also performed a qualitative study exploring the experiences of people who followed the Cross Bracing Protocol and are planning a multi-site randomised controlled trial to compare the outcomes of patients with acute ACL rupture managed with early ACL reconstruction to those of patients managed with the Cross Bracing Protocol.



**Figure 3a and b:** Early-stage Bracing.  
**Figure 4:** Early-stage rehabilitation – bracing phase.



**Figure 5a, b, and c:** Early – mid stage bracing phase rehabilitation.



**Figure 6a and b:** Late-Stage Rehabilitation – post bracing phase.



We hope that this research, including a randomized controlled trial, will provide evidence to inform clinical practice.

**SUMMARY**

This research provides further evidence of the capacity of a ruptured ACL to heal without surgery and of the association between ACL healing and favourable patient outcomes. These findings suggest that a novel bracing protocol may facilitate ACL healing at a higher rate than occurs with rehabilitation alone, although further research is needed.

**References**

1. *Filbay SR, Roemer FW, Lohmander LS, Turkiewicz A, Roos EM, Frobell R, et al. Evidence of ACL healing on MRI following ACL rupture treated with rehabilitation alone may be associated with better patient-reported outcomes: a secondary analysis from the KANON trial. British Journal of Sports Medicine. 2023;57(2):91-8.*
2. *Filbay SR, Dowsett M, Jomaa MC, Rooney J, Sabharwal R, Lucas P, et al. Healing of acute anterior cruciate ligament rupture on MRI and outcomes following non-surgical management with the Cross Bracing Protocol. British Journal of Sports Medicine. 2023;bjsports-2023-106931.*
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