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Original Article

# A Simple Magnetic Resonance Scoring System for Predicting Suitability for Primary Anterior Cruciate Ligament Repair

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## ABSTRACT

**Objective:** This study developed a simple magnetic resonance imaging (MRI) scoring method to assess the suitability of the anterior cruciate ligament (ACL) remnant for primary repair and aimed to test the success of this scoring method on operative images of patients undergoing early ACL surgery.

**Methods:** The video-recorded operative images of patients who underwent ACL reconstruction and the MRI images of the same patients taken in our hospital were retrieved from the hospital archive. Two surgeons evaluated whether the ACL could be primarily repaired on the video images recorded during the operation. Magnetic resonance primary repairability (MPR) scores and repairability status on video images were compared.

**Results:** The mean age of the patients was 30.4 ± 8.6 years. The evaluation of remnant size on MRI showed moderate agreement between observers ($P < .001$, Cohen's kappa = 0.605). The assessment of the repairability score based on MRI and video observation demonstrated substantial agreement between observers ($P < .001$, Cohen's kappa = 0.743 and $P < .001$, Cohen's kappa = 0.762, respectively).

**Conclusion:** The MR primary repairability score (MPR score) is suitable for use in the decision-making process for the primary repair of the ACL.

**Keywords:** ACL, MRI, primary, reconstruction, repair

## INTRODUCTION

ACL injuries are common in orthopedic practice, yet the ideal treatment remains controversial.[1] Historically, primary ACL repair was favored in the 1970s but fell out of favor due to suboptimal results, leading to the rise of ligament reconstruction techniques in the 1980s.[2] Recent advancements in arthroscopic techniques have renewed interest in primary ACL repair, showing promising medium to long-term results, particularly for acute injuries and those close to the femoral adhesion site.[3-5]

A critical aspect of ACL injury management is the preoperative assessment of the injury, primarily conducted through magnetic resonance imaging (MRI). MRI is invaluable in evaluating the extent, level, and tissue quality of ACL tears. Radiology literature extensively documents MRI's role in diagnosing ACL injuries; however, there is a notable paucity of information in orthopedic literature regarding MRI's accuracy in assessing the suitability of ACL remnants for primary repair.[6] Determining the quality and repairability of the ACL remnant is crucial for surgical planning and predicting outcomes.[7]

This study aims to bridge this knowledge gap by developing and testing a simple MRI-based scoring method to assess the suitability of ACL remnants for primary repair. By establishing a reliable and reproducible scoring system, this research seeks to enhance preoperative planning, optimize patient selection for primary ACL repair, and ultimately improve surgical outcomes. Through this investigation, we hope to contribute to the growing body

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of evidence supporting primary ACL repair and provide orthopedic surgeons with a valuable tool for decision-making in ACL injury management.

## MATERIAL AND METHODS

### Study Design

This retrospective study was conducted with the approval of a local ethical committee (Ethical committee approval number: E-40839667-50.04-109, Mudanya University Ethical Committee, 12.03.2024) and adhered to the principles outlined in the 'Declaration of Helsinki'. Informed consent was obtained from the patients before any surgical intervention and for the study.

A total of 256 patients who underwent ACL reconstruction in our clinic between 2016 and 2023 were retrospectively identified. We included 34 patients who had MRI imaging in our hospital within one month of ACL injury and underwent ACL reconstruction within the same timeframe. Exclusion criteria included patients with MRIs from other hospitals or surgeries performed later than 1 month post injury. The study utilized video-recorded operative images and MRI images from our hospital archive. Two orthopedic surgeons independently assessed the MRI images and calculated the ACL repairability score using our developed MR scoring system.

### New Scoring System Description

The new MR scoring system was inspired by a study by van Der List and DiFelice,[7] which classified ACL remnant length and tissue quality on MR images. In this study, the length and quality of the anterior cruciate ligament remnant on MR images were meticulously categorized. Based on the extent of ligament rupture, the presence of 90% or more cruciate ligament remnant at the distal level was classified as type 1, 90-75% as type 2, and 75-25% as type 3.

Furthermore, the tissue quality of the ligamentous remnant in MR images was categorized into three classes. If the fibrils of the ligamentous remnant were aligned in the same direction, the T1 signal was homogeneous, the T2 signal intensity was low (black), and there was no fluid appearance in the ligament, the tissue quality was classified as good. If most of the fibrils of the ligamentous remnant were aligned in the same direction, the T1 signal was slightly heterogeneous, the T2 signal intensity was moderate (dark gray), and there was some fluid appearance in the ligament, the tissue quality was classified as moderate. If the fibrils of the ligamentous remnant were in different directions, the T1 signal was heterogeneous, the T2 signal intensity was high (dark gray), and there was significant fluid appearance in the ligament, the tissue quality was determined as poor.

According to the results of the study, 89% of type 1 tears were found to be suitable for primary repair regardless of tissue quality. Based on this finding, a type 1 tear with 90% ligamentous remnant length alone is an indication for primary repair, and consequently, a type 1 tear receives 2 points in our scoring system. In the case of type 2 tears, the primary repair rate is 87% when the tissue quality is good; however, if the tissue quality is fair, the repair rate drops to approximately 22%. Therefore, 1 point was assigned for type 2 and 1 point for good tissue quality. Type 3 tears, as well as moderate and poor tissue quality categories, receive 0 points.

This scoring system was named the "MR primary repairability score (MPR score)" (Figure 1). We hypothesized that cases with a score of 2 according to preoperative MR images would be suitable for primary repair.

### Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) 26.0 (IBM SPSS Corp.; Armonk, NY, USA). Numeric variables were reported as means and standard deviations. Inter-observer reliability was assessed using Cohen's kappa.[8] Intra-observer correlation between MRI ratings and

### MAIN POINTS

- The primary repairability of the anterior cruciate ligament (ACL) remnant can be accurately predicted using preoperative MRI images assessed by orthopedic surgeons.
- The MPR score is a practical tool that can be utilized preoperatively to predict the repairability of the ACL remnant.
- The validation of the MPR score should be further evaluated through high-level evidence studies.

| MR Primary Repairability Score (MPR Score) | |
|---|---|
| Over %90 ACL remnant present (Type 1) * | 2 Points |
| %75-90 ACL remnant present (Type 2) * | 1 Points |
| Below %75 ACL remnant present (Type 3) * | 0 Points |
| Good tissue quality* | 1 Points |
| Poor tissue quality* | 0 Points |

**Figure 1.** Anterior cruciate ligament primary repairability score based on magnetic resonance images. *ACL remnant length and quality classification according to van Der List and DiFelice.[7]

**Table 1.** Demographic Data

| | | n (%) | Min-Max (Mean) | X ± ss |
|---|---|---|---|---|
| Sex | Female | 4 (11.8) | | |
| | Male | 30 (88.2) | | |
| | Total | 34 (100) | | |
| Age | | | 16-47 (30.4) | 30.4 ± 8.6 |
| Duration of injury (days) | | | 2-25 (15.17) | 15.17 ± 7.5 |
| Duration of Surgery (days) | | | 3-29 (20.23) | 20.23 ± 7.96 |

video observations was evaluated using Pearson correlation. P-values below 0.05 were considered statistically significant. The ROC curve analysis was conducted for the MPR score results provided by the first and second observers.

## RESULTS

### Demographic Data

The mean age of the 34 patients was 30.4 ± 8.6 years (range: 16 to 47). The mean duration from injury to MRI was 15.17 ± 7.5 days, and the mean duration from injury to surgery was 20.23 ± 7.96 days (Table 1).

### Inter-observer Agreement

The evaluation of remnant size on MRI showed moderate agreement between observers ($P < .001$, Cohen's kappa = 0.605). However, the evaluation of remnant tissue quality showed fair agreement ($P = .082$, Cohen's kappa = 0.256) (Tables 2 and 3).

### Repairability Score Agreement

The assessment of the repairability score based on MRI and video observation demonstrated substantial agreement between observers ($P < .001$, Cohen's kappa = 0.743 and $P < .001$, Cohen's kappa = 0.762, respectively). A significant correlation was found between the MRI repairability score and video observation for both observers (Observer 1: $P < .001$, $r = 0.592$; Observer 2: $P < .001$, $r = 0.699$) (Tables 4, 5, and 6).

### ROC Curve Analysis

The ROC curve analysis for the MPR score results of Observer 1 and Observer 2 reveals notable differences in model performance. The ROC curve for Observer 1 rises steeply towards the top-left corner, indicating

**Table 2.** The Evaluation of Remnant Size on MRI Kappa: 0.605

| | | MR Remnant 2 | | | | Symmetric Measures | | |
|---|---|---|---|---|---|---|---|---|
| | | <75% | 75-90 | >90% | Total | | Kappa Value | *P* |
| MR Remnant 1 | <75% | 15 (44.12%) | 2 (5.88%) | 0 | 17 | Measure of Kappa Agreement | 0.605 | **.000*** |
| | 75-90 | 4 (11.77%) | 7 (20.58%) | 1 (2.94%) | 12 | | | |
| | >90% | 0 | 1 (2.94) | 4 (11.77%) | 5 | | | |
| | Total | 19 | 10 | 5 | 34 | | | |

*$P < .05$ statistically significant difference.

**Table 3.** The Evaluation of Remnant Tissue Quality Kappa: 0.256

| | | Remnant Quality 2 | | | Symmetric Measures | | |
|---|---|---|---|---|---|---|---|
| | | Bad | Good | Total | | Kappa Value | *P* |
| Remnant quality 1 | Bad | 14 (41.18%) | 2 (5.88%) | 16 | Measure of Kappa Agreement | 0.256 | .082 |
| | Good | 11 (32.35%) | 7 (20.59%) | 18 | | | |
| | Total | 25 | 9 | 34 | | | |

*$P < .05$ statistically significant difference.

**Table 4.** The Assessment of the Repairability Score Based on MRI and Video Observation Kappa: 0.743

| | | Score repairability 2 | | | Symmetric Measures | | |
|---|---|---|---|---|---|---|---|
| | | No | Yes | Total | | Kappa Value | p |
| Score repairability 1 | No | 20 (%58,82) | 1 (%2,94) | 21 | Measure of Kappa Agreement | 0.743 | **0.000*** |
| | Yes | 3 (%8,83) | 10 (%29,41) | 13 | | | |
| | Total | 23 | 11 | 34 | | | |

*$P < 0.05$ statistically significant difference.

**Table 5.** The Assessment of the Repairability Score Based on MRI and Video Observation Kappa: 0.762

| | | Video Repairability 2 | | | Symmetric Measures | | |
|---|---|---|---|---|---|---|---|
| | | No | Yes | Total | | Kappa Value | p |
| Video repairability 1 | No | 17 (%50) | 1 (%2,94) | 18 | Measure of Kappa Agreement | 0.762 | **0.000*** |
| | Yes | 3 (%8,82) | 13 (%38,24) | 16 | | | |
| | Total | 20 | 14 | 34 | | | |

*$P < 0.05$ statistically significant difference.

**Table 6.** Correlation between Observer 1's (Kappa: 0.582) and Observer 2's (Kappa: 0.686) MRI Reparability Score and Video Observation

| | | Video Repairability 2 | | | Symmetric Measures | | |
|---|---|---|---|---|---|---|---|
| | | No | Yes | Total | | Kappa Value | p |
| Video Repairability 1 (Observer 1) | No | 16 (%47,06) | 5 (%14,71) | 21 | Measure of Kappa Agreement | 0.582 | **0.001*** |
| | Yes | 2 (%5,88) | 11 (%32,35) | 13 | | | |
| | Total | 18 | 16 | 34 | | | |
| Video Repairability 1 (Observer 2) | No | 19 (%55,88) | 4 (%11,77) | 23 | Measure of Kappa Agreement | 0.686 | **0.000*** |
| | Yes | 1 (%2,94) | 10 (%29,41) | 11 | | | |
| | Total | 20 | 14 | 34 | | | |

high sensitivity at low false positive rates, and levels off, reflecting a gradual increase in sensitivity with increasing false positive rates (Figure 2). This model has an AUC of 0.788, suggesting it performs well but is not perfect. In contrast, the ROC curve for Observer 2 similarly rises sharply initially but maintains a smoother incline, resulting in a higher AUC of 0.832 (Figure 3). This indicates that the model for Observer 2 is better at distinguishing between classes compared to Observer 1. Both models show good performance, significantly better than random guessing,

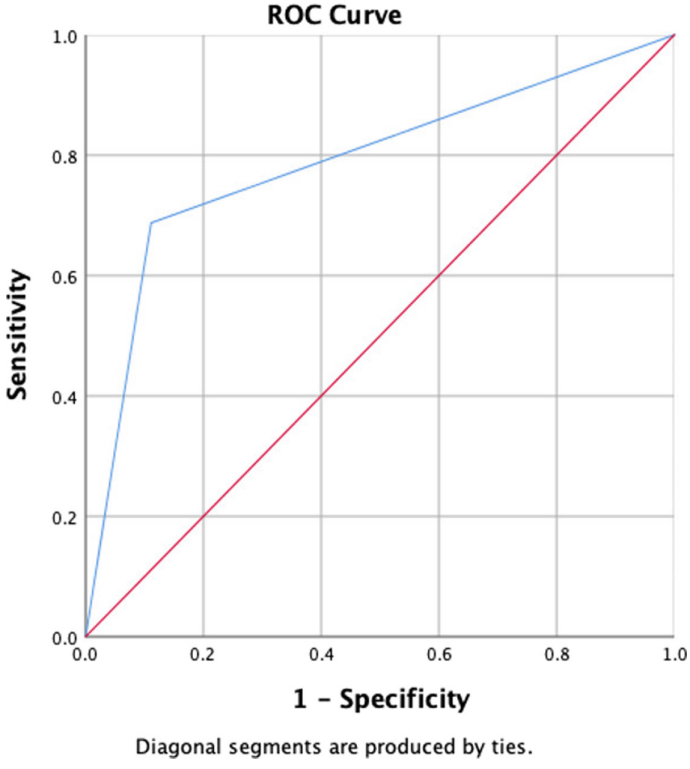


**Figure 2.** ROC curve analysis for the score results of Observer 1.

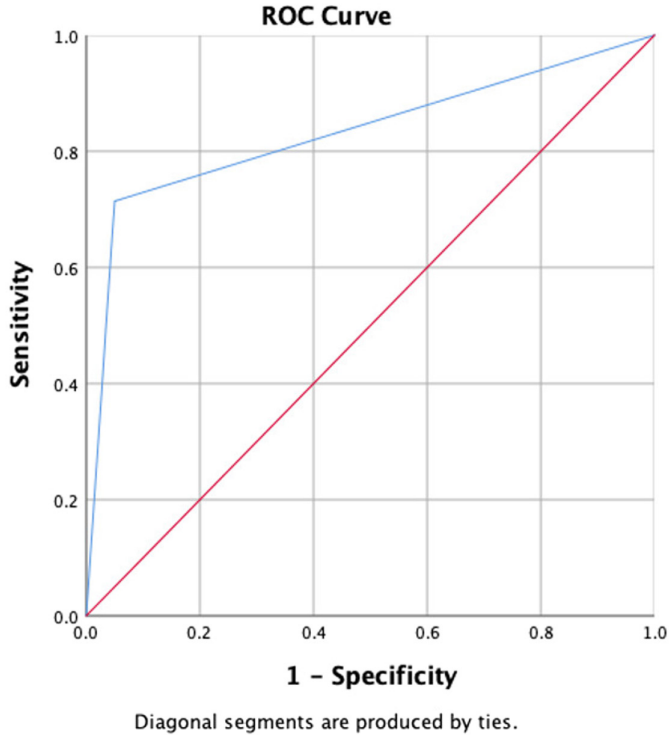


**Figure 3.** ROC curve analysis for the score results of Observer 2.

but the model for Observer 2 demonstrates superior discriminative ability across different thresholds.

## DISCUSSION

The primary anterior cruciate ligament (ACL) repair method has seen a resurgence in interest due to advancements in arthroscopic techniques and a better understanding of injury patterns and tissue quality.[9] This study aimed to develop and evaluate a novel and simple MRI-based scoring system, the MR primary repairability score (MPR score), to predict the suitability of ACL remnants for primary repair. The findings suggest that the MPR score is a reliable tool for preoperative assessment and decision-making in the context of ACL injuries.

The concept of primary ACL repair is not new, as it was a common practice in the 1970s before falling out of favor in the 1980s due to suboptimal outcomes compared to reconstruction techniques.[10] However, recent studies have revisited primary repair, demonstrating promising results when performed in selected cases, particularly with proximal tears and good tissue quality.[11] Our study builds on this renewed interest by providing a structured, reproducible scoring system based on MRI findings, which can help in the preoperative planning and patient selection process.

### Inter-Observer Reliability

One of the significant findings of our study is the substantial agreement between observers in evaluating the repairability score both on MRI and video observations (Cohen's kappa = 0.743 and 0.762, respectively). This indicates that the MPR score is a reliable tool that can be consistently used by different surgeons, reducing variability in surgical decision-making. However, the evaluation of remnant tissue quality on MRI showed only fair agreement between observers (Cohen's kappa = 0.256), suggesting that this aspect may require further refinement or additional training to improve consistency. Considering ROC curves for two observers, both observers performed significantly better than random guessing, but the model for Observer 2 demonstrated superior discriminative ability.

### Clinical Implications

The use of the MPR score could streamline the decision-making process for primary ACL repair, allowing for more accurate patient selection. This is crucial as primary repair offers several advantages over reconstruction, including preservation of the native ligament, less invasiveness, and potentially quicker rehabilitation and recovery.[12] By accurately identifying patients who are suitable candidates for primary repair, surgeons can optimize outcomes and minimize the risks associated with inappropriate patient selection.

### Correlation with Intraoperative Findings

Our study demonstrated a significant correlation between the MRI-based MPR score and intraoperative findings during arthroscopic evaluation. This reinforces the utility of the MPR score as a preoperative tool that can reliably predict intraoperative suitability for primary repair. Such predictive accuracy is vital for preoperative planning, patient counseling, and surgical strategy.

### Review of the Literature

In a study, Mehier et al. demonstrated that MRI accurately determines ACL tear location and tissue quality, with a diagnostic accuracy of 70% for tear location and up to 90% for tissue quality using the simplified MRI Sherman tissue quality classification.[6] In 2020, Vermeijden et al. showed that tear location could reliably be quantified on MRI by assessing distal and proximal remnant lengths and may assist orthopedic surgeons in evaluating which patients are eligible for primary ACL repair preoperatively.[13] However, they did not consider tissue quality. These findings highlight MRI's potential to aid clinicians in predicting ACL tear reparability. In a study by Anderson et al., the authors concluded that inter- and intra-observer reliability of MR images was not sufficient for predicting eligibility for primary ACL repair.[14]

### Limitations

Despite the promising results, our study has several limitations. The retrospective design and the relatively small sample size (34 patients) may limit the generalizability of the findings. Additionally, all MRI evaluations were performed within a single institution, which might introduce a selection bias. Future studies with larger, multi-center cohorts are needed to validate the MPR score further and explore its applicability in diverse clinical settings.

Another limitation is the moderate inter-observer agreement in evaluating remnant size on MRI (Cohen's kappa = 0.605) and the fair agreement for tissue quality assessment. These findings suggest that while the scoring system is promising, there is room for improvement in standardizing MRI interpretation among different observers. Enhanced training and potentially more detailed imaging protocols could help mitigate this issue.

### Future Directions

Future research should focus on validating the MPR score in larger, prospective cohorts and across multiple institutions to ensure its robustness and applicability in various clinical environments. Additionally, exploring the integration of advanced imaging techniques, such as three-dimensional MRI and machine learning algorithms, could enhance the accuracy and reliability of preoperative assessments.

The MR primary repairability score (MPO score) is a reliable tool for assessing the suitability of ACL remnants for primary repair. Further studies with larger sample sizes are needed to validate these findings.

**Data Availability Statement:** The data that support the findings of this study are available on request from the corresponding author.

**Ethics Committee Approval:** This study was approved by Mudanya University Ethical Committee (approval number: E-40839667-50.04-109, date: 12.03.2024).

**Informed Consent:** Informed consent was obtained from the patients who agreed to take part in the study.

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**Author Contributions:** Concept – Y.O.K., S.E.G.; Design – Y.O.K., S.E.G.; Supervision – Y.O.K., S.E.G.; Resources – Y.O.K., S.E.G.; Materials – Y.O.K., S.E.G.; Data Collection and/or Processing – Y.O.K., S.E.G., H.B.Y., G.K.; Analysis and/or Interpretation – Y.O.K., S.E.G., H.B.Y., G.K.; Literature Search – Y.O.K., S.E.G., H.B.Y., G.K.; Writing Manuscript – Y.O.K., S.E.G., H.B.Y., G.K.; Critical Review – Y.O.K., S.E.G., H.B.Y., G.K.; Other – Y.O.K., S.E.G., H.B.Y., G.K.

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