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Research Paper

Anterior Cruciate Ligament reconstruction with Bone-Tendon-Bone and Medial Collateral Ligament augmentation with semitendinosus to correct chronic anteromedial rotator instability of the knee: A prospective single-center study

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Abstract

Introduction: Anterior Cruciate Ligament (ACL) reconstruction in patients with a more than one-year rupture is associated with Anteromedial Rotator Instability (AMRI). Additional procedures to correct developmental AMRI have demonstrated improved outcomes compared to isolated ACL reconstruction. Purpose: ACL reconstruction and Medial Collateral Ligament (MCL) augmentation will restore the AMRI.

Aim: In this study, we present a unique approach to treating chronic AMRI. We observed the development of chronic AMRI in patients who had neglected their ACL rupture.

Material and methods: In this prospective single-arm case series, 32 patients with chronic AMRI (more than 1 year since injury) were included. A Bone-Tendon-Bone (BTB) graft for ACL reconstruction and semitendinosus tendon augmentation of the MCL were performed, and a 2-year follow-up was conducted to assess knee stability and Range of Motion (ROM).

Results and discussion: At the end of the follow-up, most patients showed a significant improvement in their International Knee Documentation Committee (IKDC) scores, with knee stability restored to normal in 90.7% of cases. These findings demonstrate substantial post-operative improvement following the combined ACL reconstruction and MCL augmentation.

Conclusions: The BTB reconstruction of the ACL with an augmented MCL was associated with significant improvement in knee stability and functional scores in patients with chronic AMRI. This technique requires minimal additional action compared to a simple BTB technique, making it a feasible option for orthopedic surgeons.

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1. INTRODUCTION

The Anterior Cruciate Ligament (ACL) provides approximately 85% of the total restraining force of anterior translation; thus, its reconstruction may not completely restore the knee's biomechanics, and it is always necessary to search directly for associated injuries.[1,2]

In 1968, Slocum described anteromedial instability after knee injury as a "pathologically increased outward rotation of the tibia on the femur."[3] Rotatory knee laxity is recognized as a frequent finding after ACL reconstruction, and the reasons behind that are multifactorial.[4,5]

Anteromedial Rotator Instability (AMRI) results from excessive valgus strain with simultaneous knee external rotation, leading to pathological anterior subluxation.[6] The posteromedial corner has been individualized as an essential restraint to AMRI.[7] The treatment of chronic AMRI demands the repair of the possible structures that may have caused it, especially MCL, whose unique structure controls both varus and rotator stability.[8,9]

Thus, correcting the knee's medial side affects MCL function.[9,10] AMRI is either clinically evaluated with physical examination findings and testing or imaging studies, such as radiography through valgus tests and MRI, which delineate the extent of the involvement of medial structures.[11]

In this study, we present a unique approach to treating chronic AMRI. We observed the development of chronic AMRI in patients who had neglected their ACL rupture.

Our treatment involved a BTB, ACL reconstruction, and MCL augmentation with semitendinosus. We hypothesized that this combined approach would improve knee stability and ROM.

This study aimed to assess clinical, functional, and objective stability outcomes following the combined procedure in patients with chronic AMRI.

2. AIM

In this study, we present a unique approach to treating chronic AMRI. We observed the development of chronic AMRI in patients who had neglected their ACL rupture.

3. MATERIAL AND METHODS

The study is a prospective, single-arm clinical case series evaluating the outcomes of ACL reconstruction with BTB graft combined with MCL augmentation using the semitendinosus tendon in patients with chronic AMRI.

We considered a chronic injury to be any ACL rupture of more than one year old. We observed that many patients who presented early after the trauma showed no signs of rotational instability, but at their pre-op Assessment, they had a significant AMRI.

A total of forty-eight patients with chronic ACL rupture and suspected AMRI were initially assessed for eligibility. Sixteen patients were excluded: some did not complete the minimum 24-month evaluation, while others were lost to follow-up. Finally, thirty-two patients fulfilled all inclusion criteria, completed the 24-month follow-up and were included in the final analysis. The average age was 28.5 years, ranging between 18 and 42 years. None of the patients had any previous surgery on the affected knee. None of them had any bony axis deviation or patellar instability. Eighteen of the patients were female. The same surgeon operated on all the patients.

Before the surgery, we conducted a detailed preoperative assessment for each patient. This included a comprehensive medical history, clinical examination, standard X-ray, and knee MRI. We also conducted Lysholm scores and IKDC for every patient, providing a thorough understanding of their condition.

The two procedures were performed concurrently in patients with clinically evident AMRI, based on physical examination demonstrating persistent anterior subluxation of the medial tibial plateau and increased valgus rotation in order to restore the knee's rotational stability and support overall joint function.

3.1. Anterior Cruciate Ligament reconstruction

We used the BTB technique for the ACL reconstruction. All the patients were operated under general anesthesia and saphenous block under ultrasound guidance. A tourniquet was applied in all of the cases. The lower limb was prepared and draped in a sterile fashion. The BTB was harvested through an approximately 4 cm longitudinal incision on the patellar tendon. The averages of the bony plug dimension were 6–7 mm on the femoral side and 7–8 mm on the tibial side. Arthroscopy evaluation was performed, and concomitant meniscal or chondral lesion were addressed accordingly. After the ACL remnants were cleaned, femoral and tibial tunnels were drilled according to the anatomical technique, usually 1–1.5 mm more significant than the graft measurement. The tibial tunnel was created through a second incision over the pes anserinus. The prepared graft was passed through the tunnels and fixated with bioabsorbable interference screws on both tunnels, usually 1mm smaller than the tunnels. A posterior drawer was performed during the graft tensioning. The surgical steps of the ACL reconstruction are illustrated in Figure 1.

3.2. Medial Collateral Ligament augmentation

Only the semitendinosus tendon on the same side was individualized and harvested with an open graft harvester, preserving the attachment of the semitendinosus tendon. The harvested tendon was approximately 12–14 cm long. The medial epicondyle was located by palpation or with an image intensifier in obese patients. A 2 cm incision on the medial epicondyle was made, followed by drilling 30 mm into the femur according to the ST thickness (typically 4.5–5.5 mm). The tendon was shuttled subcutaneously to the epicondyle incision and then through the femoral epicondyle tunnel. Fixation was achieved at 45 degrees of flexion using a bioabsorbable interference screw that was 1 mm larger than the

tunnel. After fixing the ST, it can be confirmed that the anterior positioning of the ST relative to the MCL was accurate. In our initial cases, we sutured the graft to the MCL for actual augmentation, but later, we found this step unnecessary. Following this, drainage, wound suturing, and soft bandaging were performed. No immobilization was required. Figure 2 provides a schematic overview of the MCL augmentation procedure using a semitendinosus graft.

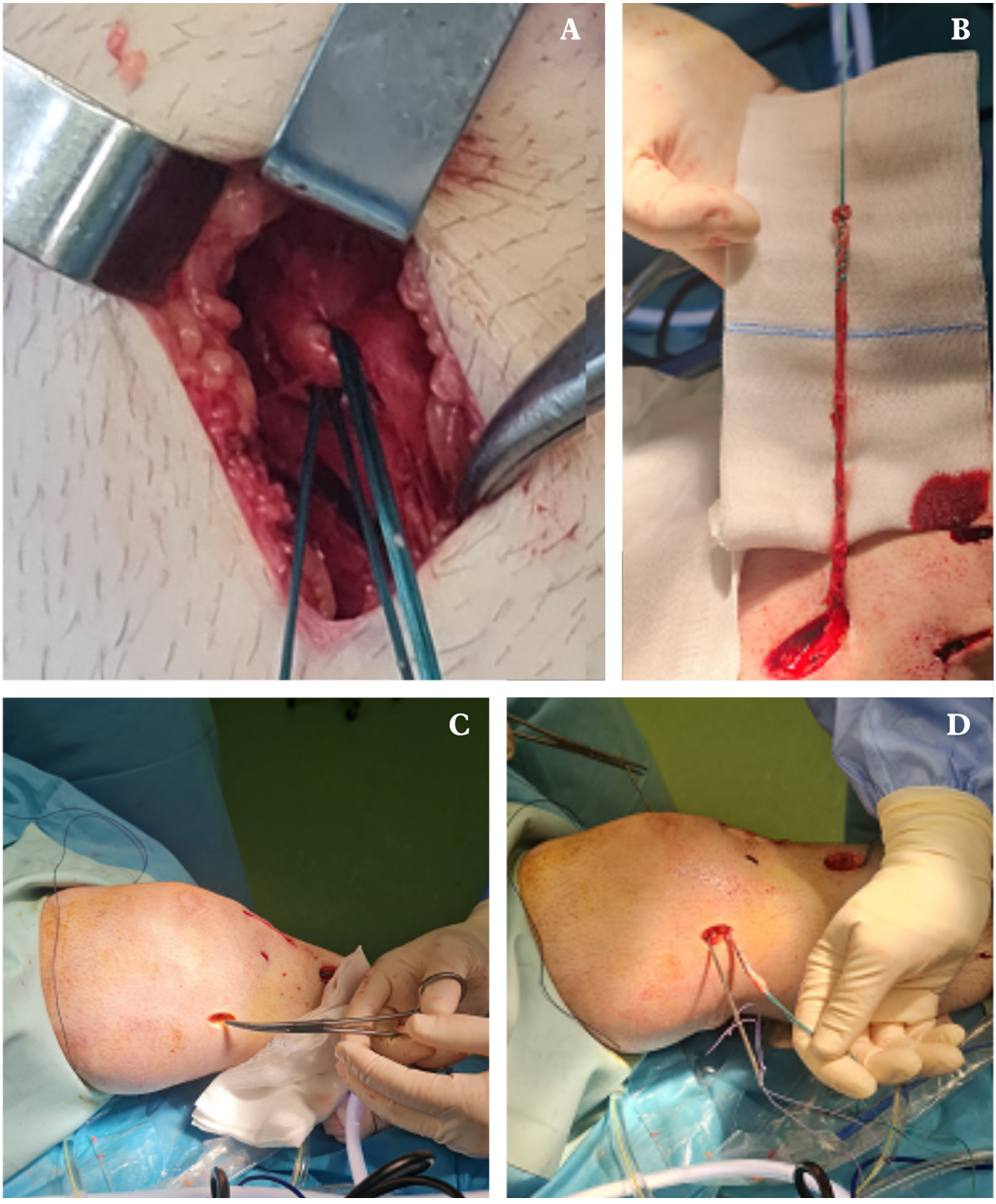

Figure 1. Operator procedure of Anterior Cruciate Ligament reconstruction.

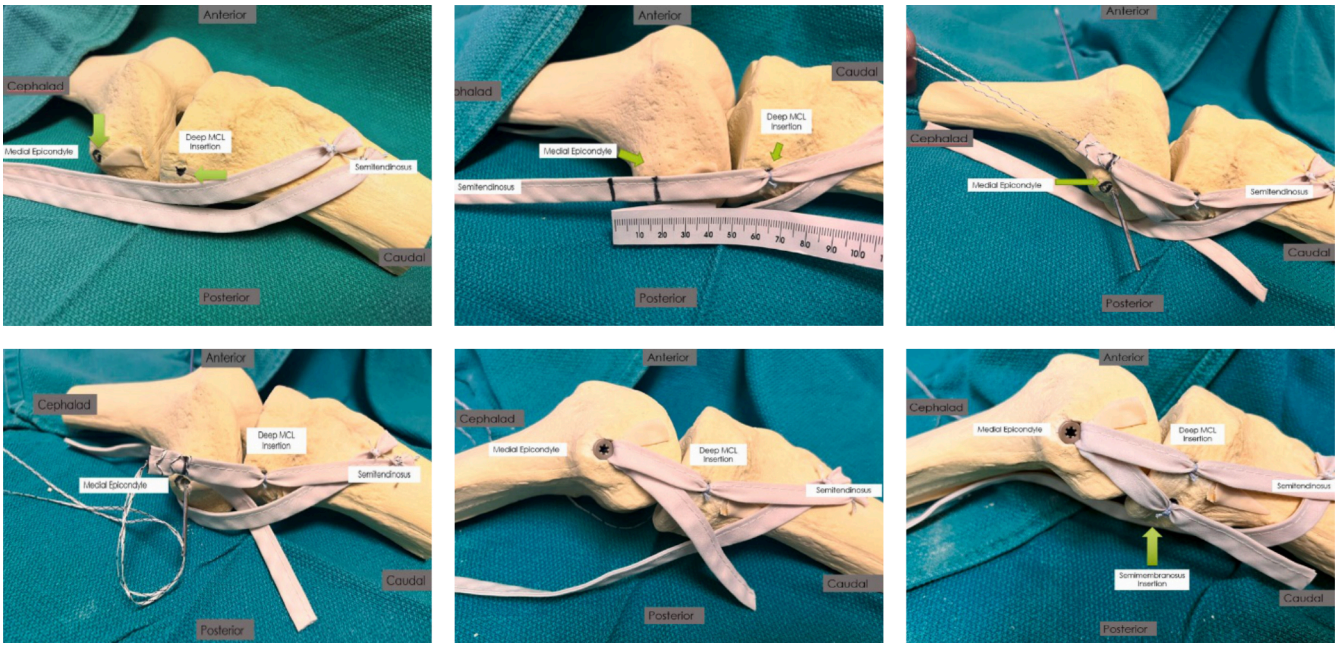

Figure 2. Illustrative depiction of the surgical steps for MCL augmentation using a semitendinosus graft.

The study was designed as a prospective single-arm clinical case series, which evaluates the outcomes of this combined surgical technique.

3.3. Ethical approval

This study was approved by the Local Bioethics Committee. Written informed consent was obtained from all patients participating in the study.

3.4. Postoperative care

As per the standard schemes, RICE, antibiotics, NSAIDs, and anticoagulation were prescribed. The patients were mobilized the same day with crutches and partial weight bearing. The antibiotic was stopped on the fifth day. The anticoagulation was necessary for four weeks postoperatively. Passive movement was encouraged on the first day. The active flexion and extension began on the third day. Physiotherapy encouraged crutches-free walking with full weight bearing between the second and the third week postoperative. No knee brace was required for use.[12] Returning to complete sports activities was allowed at the point of muscle mass regain, and the required stability tests were overcome.[13]

3.5. Evaluation

The senior surgeon evaluated all the patients before and after the operation. We assessed the standard IKDC, objective Lysholm score, and ROM. We used a KT 1000 arthrometer (Karl-Storz company) with ipsilateral side comparison at 20° flexion according to the IKDC criteria. External valgus rotation was evaluated clinically and radiographically at 20°. The AMRI was also estimated clinically using the Slocum test, and by provoking an anterior subluxation of the medial plateau through an anterior drawer with the foot in external rotation. The presence of the medial tibial plateau anterior subluxation and the increased valgus rotation was used to classify AMRI as positive or negative, according to previously established criteria (Slocum, 1968; Engebretsen & Lind, 2015).[3]

3.6. Statistical analysis

Statistical analysis was performed using SPSS software (IBM Corp., USA). Pre-operative and post-operative continuous variables were compared using the t-test for normally distributed data. For variables that were not normally distributed, the Wilcoxon signed-rank test, a standard non-parametric method for paired comparisons in orthopedic outcome studies, was applied to assess the changes between pre-operative and follow-up values. Statistical significance was set at $p < 0.05$. This approach has been previously used in Anterior Cruciate Ligament reconstruction studies to analyze pre-operative and post-operative outcomes.[14]

4. RESULTS

4.1. Patient flow and baseline characteristics

A total of forty-eight patients with chronic ACL rupture and clinically suspected AMRI were initially assessed for eligibility. Sixteen patients were excluded because they did not complete the minimum 24-month follow-up. Therefore, thirty-two patients fulfilled all inclusion criteria and completed the 24-month evaluation and were included in the final analysis. The mean age of the patients was 28.5 years (range 18–42). Eighteen patients were female. Twelve patients presented with concomitant meniscal tears; all required partial meniscectomy. No patient had previous surgery on the affected knee, bony axis deviation, or patellar

instability. All procedures were performed by the same surgical team, and all patients followed the same postoperative rehabilitation protocol.

4.2. Objective stability outcomes

Valgus rotational stability improved from 7.12 ± 0.9 mm (range 6.0–9.5 mm) preoperatively to 1.5 ± 0.5 mm (range 1.0–2.0 mm) at 24 months ($p < 0.0001$). Anterior–posterior instability improved from 9.0 ± 2.5 mm (range 7.25–14.25 mm) preoperatively to 2.0 ± 0.5 mm (range 1.0–2.75 mm) at final follow-up. The AMRI clinical test was positive in all patients preoperatively and negative at the 24-month follow-up. According to IKDC objective grading, knee stability was classified as normal in 29 patients (90.7%) and nearly normal in 3 patients (9.3%) at final follow-up.

4.3. Functional outcomes

The mean IKDC subjective score improved from 45.35 ± 6.30 (range 30–62) preoperatively to 96.80 ± 2.80 (range 91–100) at 24 months ($p < 0.0001$). The mean Lysholm score improved from 34.1 ± 5.5 (range 27–45) preoperatively to 97.0 ± 2.7 (range 89–100) at final follow-up ($p < 0.0001$). Twenty-nine patients returned to their pre-injury level of physical activity. Two patients decreased their activity level, and one patient reported an unsatisfactory functional outcome.

4.4. Range of motion

Full range of motion was restored in 31 out of 32 patients. One patient achieved 115° of flexion compared to 140° on the contralateral side and demonstrated a 5° extension deficit. All other patients achieved full active extension compared with the contralateral knee.

4.5. Complications

Eleven patients developed postoperative anteromedial crural and knee region edema. One patient developed knee stiffness requiring manipulation under general anesthesia. No infections or saphenous nerve injuries were recorded.

5. DISCUSSION

The concept of anteromedial stability means synergistic cooperation between the ACL and MCL. This study showed that AMRI develops in patients with ACL ruptures more than one year old, and augmenting the MCL to restore the knee's rotator stability is essential.

Researchers proved that chronic instability significantly increased rotator instability in old ACL despite ACL reconstruction.[15,16]

Many techniques for establishing the rotator stability of the knee are well known. Most aim at the lateral side of the knee to correct rotational stability. Some use the ipsilateral knee's hamstrings to correct rotational stability.[17]

We used the BTB tendon according to the classic version to reconstruct the ACL and the semitendinosus tendon of the same knee to augment the anterior part of the MCL without detaching it from the original insertion. The literature contains many controversies and debates. We have treated patients without apparent rupture of the MCL. Of course, treatment is necessary to achieve a good result in combined ruptures of ACL–MCL, but this was not the goal of our study.

We raised the hypothesis that augmenting the MCL in patients with chronic ACL tears older than one year will correct the AMRI. Our clinical and imaging results support that the combined technique holds a potential role in confirming our hypothesis. Although we noticed MCL/POL in many of our patients, we concluded that augmenting the semitendinosus without detachment of the insertion gave excellent results. Different authors have also confirmed this in the literature.[16,17]

The augmentation should not be considered an MCL reconstruction, but an additional support for the knee's AMRI. Previous studies have shown that isolated ACL reconstruction may not restore the knee's rotational stability to its maximum, particularly if medial-sided laxity is present. In addition, the literature on AMRI mainly consists of biomechanical investigations and small clinical series rather than comparative trials. Therefore, the present study was designed to report clinical outcomes of the combined technique rather than to establish superiority over the isolated ACL reconstruction.

The reported complications of this technique include residual rotational instability, loss of motion, and medial-side pain.[10] Although the technique addresses all the elements of knee instability, the lack of precise accurate instrumentation measurements may be considered a limitation of the study.

In our study, only one patient could not reach the entire ROM. Since this technique requires additional procedures, we expected an even more intense physiotherapy phase.

The anatomical reconstruction of the ACL and the mini-invasive MCL augmentation are key factors in decreasing postoperative pain and early ROM gain following the rehabilitation protocols that allow early weight bearing and movement of the knee.[18]

Medial joint pain, usually a common finding after MCL repairs, was evaluated subjectively. The mini-invasive (percutaneous) augmentations and the avoidance of tensioning play a significant role in medial joint pain. Seven of our patients complained during the first three postoperative months of the MJP.

This technique is easy and can be performed without involving the other knee. It offers excellent rotational stability in chronic ACL ruptures over one year, and AMRI has been developed. Further studies are necessary to establish the knee's rotational instability and accurate measurement possibilities.

5.1. Limitations

A major limitation of this study is the absence of a control group treated with isolated ACL reconstruction, which prevents determining the independent contribution of MCL augmentation and introduces potential sources of selection and observer bias. The present findings demonstrate an association

between the combined procedure and improved clinical outcomes rather than a causal relationship. Furthermore, all procedures were performed by a single surgeon and evaluated by a single investigator, without patient randomization. While standardized surgical techniques and rehabilitation protocols were applied consistently to all patients to minimize variability, these factors may introduce a potential bias and, therefore, limit the generalizability of our results. In addition, the method used for quantitatively diagnosing rotational anteromedial instability relied on clinical tests (Slocum test, valgus stress) and KT-1000 measurements rather than advanced biomechanical instrumentation or dynamic imaging. These methods, however, are widely accepted in clinical practice and provide a reliable assessment of anteromedial rotatory laxity (Slocum, 1968; Engebretsen & Lind, 2015). Future multicenter, randomized studies with appropriate control groups are required to confirm these observations and to better delineate the individual effects of the combined technique. Alongside this, the use of subjective clinical scoring systems such as IKDC and Lysholm may introduce measurement bias. The relatively small sample size may also limit statistical power and increase the risk of a type I error. These factors should be considered when interpreting the results.

6. CONCLUSION

ACL reconstruction using a BTB graft, combined with semitendinosus MCL augmentation, was associated with significant improvements in knee stability, ROM, and functional scores in patients with chronic AMRI. However, as this was a single-arm cohort study, these observed improvements reflect an association and not a definitive causation. Future randomized controlled studies are needed to confirm these findings and clarify the independent role of MCL augmentation in chronic AMRI.

LIST OF ABBREVIATIONS

ACL – Anterior Cruciate Ligament
AMRI – Anteromedial Rotator Instability
BTB – Bone-Tendon-Bone
IKDC – International Knee Documentation Committee
MCL – Medial Collateral Ligament
MRI – Magnetic Resonance Imaging
NSAID – Non-Steroidal Anti-Inflammatory Drugs
RICE – Rest, Ice, Compression, Elevation
ROM – Range of Motion

Ethics approval
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Conflict of interest
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Author contributions
Study design: DT, PA
Data collection: FM, GP
Statistical analysis: FP, AA
Data interpretation: AP, AD
Manuscript preparation: DT, PA, GP
Literature search: FP, AP
Funds collection: FM, AD

References
1 Gonzalez-Pola R, Gómez Mont-Landerreche JG, Herrera-Lozano A, et al. Rotational instability of the knee: Injury of the anterior cruciate and anterolateral knee ligaments, MRI findings. *J Muscuoscelet Surg Res*. 2021;5:24–9. https://doi.org/10.4103/jmsr.jmsr_68_20.
2 Fu FH, van Eck CF, Tashman S, et al. Anatomic anterior cruciate ligament reconstruction: A changing paradigm. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(3):640–648. https://doi.org/10.1007/s00167-014-3209-9.
3 Slocum DB, Larson RL. Rotatory instability of the knee: Its pathogenesis and a clinical test to demonstrate its presence. *J Bone Joint Surg*. 1968;50–A:211–225.
4 Zantop T, Schumacher T, Diermann N, et al. Anterolateral rotational knee instability: Role of posterolateral structures. Winner of the AGA-DonJoy Award 2006. *Arch Orthop Trauma Surg*. 2007;127(9):743–752. https://doi.org/10.1007/s00402-006-0241-3.
5 Stephen JM, Halewood C, Kittl C, et al. Posteromedial Meniscocapsular Lesions Increase Tibiofemoral Joint Laxity With Anterior Cruciate Ligament Deficiency, and Their Repair Reduces Laxity. *Am J Sports Med*. 2016;44(2):400–408. https://doi.org/10.1177/0363546515617454.
6 Engebretsen L, Lind M. Anteromedial rotatory laxity. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):2797–2804. https://doi.org/10.1007/s00167-015-3675-8.
7 Sims WF, Jacobson KE. The posteromedial corner of the knee: Medial-sided injury patterns revisited. *Am J Sports Med*. 2004;32(2):337–345. https://doi.org/10.1177/0363546503261738.
8 Koga H, Muneta T, Yagishita K, Ju YJ, et al. Surgical management of grade 3 medial knee injuries combined with cruciate ligament injuries. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(1):88–94. https://doi.org/10.1007/s00167-011-1541-x.
9 Badran A, Elganiny M, Elrhman A. Chronic anteromedial rotatory instability of the knee: Technique and results of a near-anatomical reconstruction. *Egypt Orthop J*. 2019;54(2):126–132. https://doi.org/10.4103/eoj.eoj_27_19.
10 Robinson JR, Bull AM, Amis AA. Structural properties of the medial collateral ligament complex of the human knee. *J Biomech*. 2005;38(5):1067–1074. https://doi.org/10.1016/j.jbiomech.2004.05.034.

11 Hughes JD, Rauer T, Gibbs CM. Diagnosis and treatment of rotatory knee instability. *J EXP ORTOP* 6. 2019;48. https://doi.org/10.1186/s40634-019-0217-1.

12 Todhe D, Cipi R, Hysenaj A. Internal brace ligament augmentation vs. anatomical repair with hamstrings of the ACL – a clinical data comparison study. Open Access Macedonian Journal of Medical Sciences, VOL.10 A: Basic Sciences Sports Medicine 2022. https://doi.org/10.3889/oamjms.2022.11013.

13 Rodrigues CAS, Albano TR, Pereira Melo AK, et al. Y-Balance Test after ACL Reconstruction: The relationship with knee and hip muscle strength, ankle dorsiflexion range of motion and postural stability. *J Bodyw Mov Ther*. 2024;40:2099–2104. https://doi.org/10.1016/j.jbmt.2024.10.016.

14 Liau ZQG, Thirukumaran K, Yeo KZG, Mok YR, Lee YHD. Outcomes of ACL Reconstruction with Concomitant Meniscal Surgery: A Retrospective Cohort Study. *Orthop J Sports Med*. 2025. Available from: https://pubmed.ncbi.nlm.nih.gov/40470515/. Accessed: December 20, 2025.

15 Zaffagnini S, Bignozzi S, Martelli S, et al. Does ACL reconstruction restore knee stability in combined lesions? An in vivo study. *Clin Orthop Relat Res*. 2007;454:95–99. https://doi.org/10.1097/BLO.0b013e31802b4a86.

16 Canata GL, Chiey A, Leoni T. Surgical technique: Does mini-invasive medial collateral ligament and posterior oblique ligament repair restore knee stability in combined chronic medial and ACL injuries? *Clin Orthop Relat Res*. 2012;470(3):791–797. https://doi.org/10.1007/s11999-011-2018-4.

17 Grapatsas K, Tsilogianni Z, Papatriantafyllou A, et al. Undiagnosed Marfan Syndrome During Military Enlistment: Challenges for Medical Qualification and a Brief Clinical Review. *Pol Ann Med*. 2025;32(2):220–224. https://doi.org/10.29089/paom/205116.

18 van Grinsven S, van Cingel RE, Holla CJ, et al. Evidence-based rehabilitation following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(8):1128–1144. https://doi.org/10.1007/s00167-009-1027-2.