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Research Article

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Micro-fragmented Adipose Tissue Enhances Graft-to-Bone Healing after Anterior Cruciate Ligament Reconstruction: A Non-blinded Randomised Controlled Trial

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List of abbreviations

ACL, anterior cruciate ligament;

MFAT, micro-fragmented adipose tissue;

MRI, magnetic resonance imaging;

SNQ, signal-to-noise quotient;

ROI, region of interest;

VAS, visual analogue scale;

IKDC, International Knee Documentation Committee;

IQR, interquartile range;

PCL, posterior cruciate ligament;

RCT, randomised controlled trial.

Abstract

Objective: Anterior cruciate ligament (ACL) reconstruction is widely used to treat ACL rupture, but graft-to-bone healing remains a key factor affecting graft maturation and postoperative stability. Micro-fragmented adipose tissue (MFAT) contains mesenchymal stem cells, extracellular matrix, and bioactive factors with anti-inflammatory and tissue-repair potential. This study aimed to evaluate the effect of local MFAT application on graft-to-bone healing, graft maturation, pain relief, and knee function after ACL reconstruction.
Methods: This prospective, single-centre, non-blinded randomised controlled trial included 40 patients with acute ACL injury. Patients were randomly assigned to a conventional ACL reconstruction group or an ACL reconstruction plus MFAT group, with 20 patients in each group. All patients underwent standard arthroscopic ACL reconstruction using a four-strand hamstring tendon graft. In the MFAT group, infrapatellar fat pad tissue was harvested, processed into MFAT, and injected around the femoral and tibial bone tunnel regions after graft fixation. Both groups followed the same postoperative rehabilitation protocol. The primary outcome was the MRI signal-to-noise quotient (SNQ) at 6 months postoperatively. Secondary outcomes included VAS pain scores, IKDC scores, and complications. Data were analysed using the Mann–Whitney U test, with $P < 0.05$ considered statistically significant.
Results: Baseline characteristics were comparable between the two groups. Operative time was longer in the MFAT group due to the additional MFAT procedure. At 6 months postoperatively, the MFAT group showed significantly lower SNQ values in ROI 1 and ROI 3 than the control group, indicating improved graft maturation and graft-to-bone healing. No significant difference was found in ROI 2. The MFAT group also had lower VAS pain scores at 3 months, while no significant difference was observed at 6 months. IKDC scores did not differ significantly between groups at 3 or 6 months. No severe complications, including infection, graft failure, or postoperative bleeding, occurred in either group.
Conclusion: Local MFAT application during ACL reconstruction may improve graft maturation and graft-to-bone healing in the femoral and tibial tunnel regions and reduce early postoperative pain, without increasing major complications. MFAT may be a promising adjunctive treatment for enhancing graft-to-bone healing after ACL reconstruction, although larger studies with longer follow-up are needed.
Trial Registration Number: The Ethics Committee of Weifang People's Hospital (approval number: KYLL20250105-5); Chinese Clinical Trial Registry (trial registration number: ChiCTR2500101018. Data of registration: 2025-04-18. Retrospectively registered).
Keywords: anterior cruciate ligament reconstruction; graft-to-bone healing; micro-fragmented adipose tissue; graft maturation; signal-to-noise quotient; knee function

1.Introduction

The anterior cruciate ligament (ACL) is an important structure for maintaining

anterior and rotational stability of the knee joint. ACL injuries commonly occur during sports activities, traffic accidents, and twisting injuries in daily life. Such injuries may lead to knee instability, pain, limited range of motion, and reduced athletic performance[1]. If not treated effectively, ACL injury may further increase the risk of meniscal injury, cartilage degeneration, and post-traumatic osteoarthritis. For young and physically active patients, or those with obvious knee instability, arthroscopic ACL reconstruction is currently a commonly used surgical treatment[2, 3].

The aim of ACL reconstruction is not only to restore knee stability, but also to promote gradual graft maturation and firm integration between the graft and the bone tunnel. Graft-to-bone healing between the graft and the femoral and tibial bone tunnels is a key factor for successful reconstruction. Previous studies have shown that insufficient healing at the graft-to-bone interface may result in inadequate fixation strength, tunnel widening, graft laxity, reduced knee stability, and even graft failure[4]. Therefore, promoting graft-to-bone healing after ACL reconstruction has become an important research focus in sports medicine and joint surgery.

At present, improvements in ACL reconstruction mainly focus on graft selection, tunnel positioning, fixation methods, and rehabilitation protocols. However, optimisation of surgical techniques alone cannot fully address delayed graft-to-bone healing and slow graft maturation. Graft-to-bone healing is a complex biological process involving local inflammatory responses, cell migration, angiogenesis, collagen remodelling, fibrocartilage formation, and bone integration. Excessive or prolonged inflammatory responses around the bone tunnel after surgery may impair graft-to-bone integration and delay the healing process.

Mesenchymal stem cells play an important role in tissue repair and regeneration. They can improve the local repair microenvironment through paracrine effects, immunomodulation, anti-inflammatory activity, and promotion of extracellular matrix remodelling[5, 6]. Adipose tissue is an abundant and easily accessible source of mesenchymal stem cells. Micro-fragmented adipose tissue (MFAT) is obtained by gentle mechanical processing of autologous adipose tissue and preserves various active components, including extracellular matrix, mesenchymal stem cells, pericytes, growth factors, and extracellular vesicles[7]. Compared with isolated cells or in vitro-expanded cells, MFAT more closely resembles the natural tissue microenvironment and has good biocompatibility and potential for clinical translation .

In this study, MFAT was applied during ACL reconstruction. The aim was to improve the microenvironment around the bone tunnel through local injection, reduce postoperative inflammatory responses, and promote healing at the graft-to-bone interface. The effects of MFAT on MRI-based graft maturation, postoperative pain, knee function, and safety were further evaluated.

2.Methods

2.1 Study Design

This study was a prospective, single-centre, non-blinded randomised controlled trial designed to evaluate the effect of micro-fragmented adipose tissue (MFAT) injection on graft-to-bone healing after anterior cruciate ligament (ACL) reconstruction. A total of 40 patients with acute ACL injury were enrolled and randomly assigned to either the standard ACL reconstruction group or the ACL reconstruction combined with MFAT injection group, with 20 patients in each group. Randomisation was performed using a computer-generated random number table to minimise allocation bias. The trial was conducted from January 2025 to January 2026 at the Department of Joint Surgery, Weifang People's Hospital. The study protocol has been published previously [8].

2.2 Ethical Approval

This study was approved by the Scientific Research Ethics Committee of Weifang People's Hospital approval number KYLL20250105-5. Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the principles of the Declaration of Helsinki.

2.3 Participants

Patients were included if they met the following criteria: age between 18 and 50 years; acute ACL injury requiring surgical reconstruction; no previous surgery on the affected knee; and provision of written informed consent.

The exclusion criteria were as follows: known allergy to study-related materials or MFAT components; severe joint disease, such as advanced osteoarthritis or rheumatoid arthritis; severe ligament or meniscal injuries requiring additional surgical procedures; coagulation disorders or long-term use of anticoagulants; and pregnancy or breastfeeding.

2.4 Surgical Procedure

All patients underwent standard arthroscopic ACL reconstruction using the same surgical protocol. After satisfactory anaesthesia, the patient was placed in the supine position. Routine disinfection and draping were performed, and standard arthroscopic portals were established. The intra-articular structures of the knee were examined to confirm ACL injury and assess associated lesions.

The ipsilateral semitendinosus and gracilis tendons were harvested and prepared as a four-strand hamstring tendon graft after removal of surrounding soft tissue. Femoral and tibial bone tunnels were created according to anatomical positioning, and the graft was pulled into the tunnels. Femoral fixation was achieved using a suspensory cortical button, and tibial fixation was performed with an interference screw. After fixation, graft position, tension, and stability were confirmed arthroscopically.

In the control group, no MFAT injection was performed after standard ACL reconstruction. In the MFAT group, MFAT preparation and intra-articular injection were additionally performed after completion of graft fixation.

2.5 MFAT Preparation and Injection

In the MFAT group, infrapatellar fat pad tissue was harvested under direct arthroscopic visualisation. Approximately 10–20 mL of adipose tissue was usually obtained. The harvested tissue was immediately transferred to a sterile environment

and mechanically processed into MFAT **(Figure 1)**.

After graft fixation and confirmation of satisfactory graft position, the prepared MFAT was injected into the knee joint under arthroscopic guidance, with particular focus on the areas surrounding the femoral and tibial bone tunnels. This injection strategy was intended to allow MFAT to act directly on the graft-to-bone interface, improve the local inflammatory and repair microenvironment, and promote graft-to-bone healing.

The use of infrapatellar fat pad-derived MFAT allowed tissue harvesting to be performed during the arthroscopic procedure, avoiding additional abdominal fat harvesting and reducing procedural invasiveness.

2.6 Postoperative Rehabilitation

Both groups followed the same standardised postoperative rehabilitation protocol. In the early postoperative period, patients wore a knee brace for protection, performed isometric quadriceps exercises, and were allowed partial weight-bearing with crutches. Range-of-motion exercises were started one week after surgery and were gradually progressed.

At 4–6 weeks postoperatively, patients gradually transitioned to full weight-bearing and functional training. Crutches were discontinued progressively after 6 weeks. Progressive strengthening exercises were introduced at 3 months postoperatively, and jogging was gradually resumed at approximately 6 months according to individual recovery. The use of a unified rehabilitation protocol helped reduce the influence of rehabilitation-related differences on study outcomes.

2.7 Outcome Measures

The primary outcome was graft maturity assessed by magnetic resonance imaging signal-to-noise quotient (SNQ) at 6 months postoperatively. SNQ was used to evaluate graft maturation and graft-to-bone healing. In general, a lower SNQ value indicates that the graft signal is closer to that of a mature ligament, suggesting better graft maturation and graft-to-bone integration.

For MRI assessment, oblique sagittal images from fat-suppressed proton-density sequences were selected. Multiple regions of interest (ROIs) were defined: ROI 1 represented the femoral bone tunnel region, ROI 2 represented the intra-articular graft region, ROI 3 represented the tibial bone tunnel region, ROI 4 represented the posterior cruciate ligament reference region, and ROI 5 represented the background noise region **(Figure 2)**. SNQ was calculated using the following formula:

SNQ = (mean graft signal intensity − mean PCL signal intensity) / mean background signal intensity

Secondary outcomes included visual analogue scale (VAS) pain scores, International Knee Documentation Committee (IKDC) scores, and postoperative complications. VAS scores were used to assess pain intensity, while IKDC scores were used to evaluate knee function, stability, and activity level. Complications, including infection, postoperative bleeding, graft failure, and re-rupture, were recorded during follow-up.

2.8 Statistical Analysis

Continuous variables were expressed as medians and interquartile ranges and compared using the Mann–Whitney U test. Categorical variables were expressed as

numbers and percentages and compared using the chi-square test or Fisher's exact test, as appropriate. A value of $P < 0.05$ was considered statistically significant. MRI-SNQ values, VAS scores, IKDC scores, and complication rates were compared between groups to evaluate the effects of MFAT on graft-to-bone healing and functional recovery after ACL reconstruction.

3.Results

3.1 Baseline Characteristics and Surgical Data

The baseline characteristics of the two groups were generally similar and comparable **(Table 1)**. The operative time was significantly longer in the MFAT group than in the control group. This was mainly because additional procedures, including infrapatellar fat pad harvesting, MFAT preparation, and intra-articular injection, were performed in the MFAT group. Although the MFAT procedure increased the operative time to some extent, the entire process could be completed simultaneously during arthroscopic surgery. No serious adverse events related to MFAT preparation or injection were observed. Other outcome measures are summarised in **Table 2.**

3.2 MRI-SNQ Findings

MRI-SNQ results at 6 months postoperatively showed that graft maturation in the femoral and tibial bone tunnel regions was better in the MFAT group than in the control group.

In ROI 1, the median SNQ value was 21.3 (IQR 15.2–33.5) in the control group and 5 (IQR 1.3–12.6) in the MFAT group, with a statistically significant difference. Since a lower SNQ value indicates better graft maturation, this result suggests that MFAT may promote graft maturation and graft-to-bone integration in the femoral bone tunnel region.

In ROI 2, the median SNQ value was 40.2 (IQR 22.1–60.8) in the control group and 35.4 (IQR 27.3–55.1) in the MFAT group, with no statistically significant difference between the two groups. This finding suggests that MFAT had a relatively limited effect on signal changes in the intra-articular free portion of the graft.

In ROI 3, the median SNQ value was 27.6 (IQR 12.4–38.2) in the control group and 10.3 (IQR 4.7–15.4) in the MFAT group, with a statistically significant difference. This result indicates that MFAT may also improve graft maturation in the tibial bone tunnel region.

Taken together, the results from ROI 1 and ROI 3 suggest that MFAT had a more evident promoting effect on graft maturation and graft-to-bone integration in the bone tunnel-related regions. This is consistent with the technical design of injecting MFAT mainly around the femoral and tibial bone tunnels.

3.3 Pain Scores

VAS pain scores showed that pain was lower in the MFAT group than in the control group at 3 months postoperatively. The median VAS score was 5 (IQR 2–7) in the control group and 3 (IQR 1–5) in the MFAT group, with a statistically significant difference. This result suggests that MFAT may reduce early postoperative pain,

possibly due to its local anti-inflammatory effects and regulation of the intra-articular microenvironment.

At 6 months postoperatively, VAS pain scores became similar between the two groups. The median VAS score was 3 (IQR 1–5) in the control group and 3 (IQR 1–4) in the MFAT group, with no statistically significant difference. This indicates that pain gradually decreased in both groups as postoperative rehabilitation progressed, while the advantage of MFAT was mainly reflected in early postoperative pain control.

3.4 Knee Functional Scores

IKDC scores showed no statistically significant difference between the two groups at 3 months postoperatively. The median IKDC score was 57 (IQR 34–67) in the control group and 52 (IQR 28–72) in the MFAT group. At 6 months postoperatively, the difference in IKDC scores between the two groups also did not reach statistical significance. Although the MFAT group showed a trend towards improvement, the results were not sufficient to demonstrate a significant advantage of MFAT in knee functional recovery.

IKDC scores may be influenced by multiple factors, including preoperative activity level, muscle strength recovery, rehabilitation compliance, psychological status, and follow-up duration. The relatively limited sample size and short follow-up period in this study may have reduced the ability to detect differences in functional outcomes. Further studies with larger sample sizes and longer follow-up periods are needed to determine the effects of MFAT on postoperative knee function and return-to-sport ability.

3.5 Complications

During the study period, no serious complications, including infection, graft failure, or postoperative bleeding, occurred in either group. No obvious adverse reactions related to MFAT injection were observed. These findings suggest that, under strict indications, standardised aseptic procedures, and precise intraoperative injection, ACL reconstruction combined with MFAT injection has favourable preliminary safety.

4.Discussion

The present study evaluated the effect of local micro-fragmented adipose tissue (MFAT) application on graft maturation and graft-to-bone healing after anterior cruciate ligament (ACL) reconstruction. The main finding was that patients receiving MFAT injection showed significantly lower MRI-SNQ values in the femoral and tibial bone tunnel regions at 6 months postoperatively compared with those undergoing conventional ACL reconstruction. In addition, the MFAT group had lower VAS pain scores at 3 months after surgery, while no significant differences were observed in IKDC scores at 3 or 6 months. No severe complications related to MFAT injection occurred during the study period. These findings suggest that MFAT may have a positive effect on early graft-to-bone healing and postoperative pain relief after ACL reconstruction.

Graft-to-bone healing is a critical biological process after ACL reconstruction. After

implantation, the tendon graft must gradually integrate with the femoral and tibial bone tunnels to achieve stable fixation and long-term graft function[9]. This process involves inflammation, cell migration, angiogenesis, collagen remodelling, fibrocartilage formation, and bone integration. Inadequate healing at the graft-to-bone interface may lead to delayed graft maturation, tunnel widening, graft laxity, or even reconstruction failure[10-13]. Therefore, improving the biological environment of the bone tunnel interface has become an important strategy for enhancing the outcome of ACL reconstruction.

In this study, the SNQ values in ROI 1 and ROI 3 were significantly lower in the MFAT group than in the control group. Since lower SNQ values generally indicate a more mature graft signal on MRI, these results suggest that MFAT may promote graft maturation in the femoral and tibial bone tunnel regions. However, no significant difference was observed in ROI 2, which represented the intra-articular portion of the graft. This finding is important because it indicates that the effect of MFAT may be more localised to the graft-to-bone interface rather than evenly distributed throughout the entire graft. This is consistent with the injection strategy used in this study, in which MFAT was mainly applied around the femoral and tibial bone tunnels.

The potential mechanism by which MFAT enhances graft-to-bone healing may be related to its biological composition. MFAT preserves several active components of adipose tissue, including extracellular matrix, mesenchymal stem cells, pericytes, vascular progenitor cells, growth factors, and extracellular vesicles. Rather than acting only through direct cell differentiation, MFAT may exert its effects mainly through paracrine signalling, anti-inflammatory activity, immunomodulation, and regulation of the local repair microenvironment. After ACL reconstruction, local tissue injury, graft micromotion, and bone tunnel drilling can induce inflammatory responses[14-16]. Although moderate inflammation is necessary for initiating tissue repair, excessive or prolonged inflammation may impair collagen organisation, fibrocartilage formation, and bone integration. MFAT may help reduce excessive inflammation, promote recruitment of reparative cells, enhance angiogenesis, and support extracellular matrix remodelling, thereby creating a more favourable environment for graft-to-bone healing.

The lower VAS pain score observed in the MFAT group at 3 months postoperatively may also support the anti-inflammatory potential of MFAT. Early postoperative pain after ACL reconstruction is associated with surgical trauma, synovial irritation, intra-articular inflammatory mediators, and rehabilitation-related stimulation. By improving the intra-articular microenvironment and modulating local inflammatory responses, MFAT may contribute to early pain relief. However, the difference in VAS scores disappeared at 6 months, indicating that the analgesic effect of MFAT may be more evident in the early postoperative period. As rehabilitation progresses, pain in both groups may gradually improve, reducing the difference between groups over time.

In contrast to the imaging and pain outcomes, IKDC scores did not differ significantly between the two groups at either 3 or 6 months postoperatively. This may be explained by several factors. First, functional recovery after ACL reconstruction is

influenced by multiple variables, including preoperative activity level, muscle strength recovery, rehabilitation compliance, psychological status, and return-to-sport confidence. Second, the sample size of this study was relatively small, which may have limited the ability to detect differences in functional outcomes. Third, the follow-up period was relatively short. Improvements in graft-to-bone healing may require a longer period before they translate into measurable differences in knee function or sports performance. Therefore, although MFAT showed potential benefits in imaging-based graft maturation, its effect on functional recovery remains uncertain and requires further investigation.

The safety findings of this study are also noteworthy. No serious complications, including infection, postoperative bleeding, graft failure, or re-rupture, were observed in either group. No obvious adverse reactions related to MFAT injection were identified. In addition, the use of infrapatellar fat pad-derived MFAT allowed tissue harvesting to be performed during arthroscopic ACL reconstruction, avoiding the need for additional abdominal fat harvesting. This approach may reduce procedural invasiveness and improve clinical feasibility. Although MFAT preparation increased operative time, the procedure could be completed within the standard arthroscopic workflow.

This study has several limitations. First, it was a single-centre study with a relatively small sample size, and the findings should be interpreted with caution. Second, the study was non-blinded, which may have introduced potential assessment bias. Third, the follow-up period was limited to 6 months for the primary imaging outcome, which is insufficient to determine whether the observed improvement in graft maturation leads to better long-term knee stability, return-to-sport outcomes, or lower re-rupture rates. Fourth, the MFAT preparation method, injection volume, injection site, and optimal patient population have not yet been standardised. Future multicentre randomised controlled trials with larger sample sizes, longer follow-up periods, and more objective functional assessments are needed to confirm the long-term clinical value of MFAT in ACL reconstruction.

In summary, this study suggests that local MFAT application during ACL reconstruction may improve graft maturation in the femoral and tibial bone tunnel regions and reduce early postoperative pain without increasing major complications. These findings support MFAT as a potentially useful biological adjunct for enhancing graft-to-bone healing after ACL reconstruction. However, further high-quality studies are required before this technique can be widely recommended in clinical practice.

5.Conclusion

This study preliminarily demonstrated that local application of micro-fragmented adipose tissue (MFAT) during arthroscopic anterior cruciate ligament reconstruction may promote graft-to-bone healing. Compared with conventional ACL reconstruction, ACL reconstruction combined with MFAT injection reduced MRI-SNQ values in the femoral and tibial bone tunnel regions at 6 months postoperatively, suggesting

improved graft maturation and enhanced integration at the graft-to-bone interface.
In addition, the MFAT group showed lower VAS pain scores at 3 months postoperatively, indicating that MFAT may help relieve early postoperative pain. This effect may be associated with its local anti-inflammatory, immunomodulatory, and microenvironment-regulating properties. However, no statistically significant differences in IKDC scores were observed between the two groups at 3 or 6 months postoperatively, suggesting that the effect of MFAT on early functional recovery requires further investigation.
Regarding safety, no serious complications, including infection, graft failure, postoperative bleeding, or re-rupture, occurred in either group during the study period. No obvious adverse reactions related to MFAT injection were observed. These findings suggest that ACL reconstruction combined with MFAT injection has favourable preliminary safety and clinical feasibility when performed under strict indications, standardised aseptic procedures, and precise intraoperative injection.
In conclusion, MFAT is an autologous biological adjunct that can be harvested and applied during ACL reconstruction. It has the advantages of minimal invasiveness, convenience, and good biocompatibility. MFAT may have clinical value in promoting graft-to-bone healing, improving graft maturation, and reducing early postoperative pain. Further multicentre randomised controlled trials with larger sample sizes and longer follow-up periods are needed to confirm its long-term effects on knee stability, functional recovery, return to sport, and graft re-rupture risk.

Consent
Yes, all the patients provided informed consent prior to enrollment.

Conflicts of Interest Disclosure
None of the authors report having a conflict of interest in this study.

Data Availability Statement
This study collected primary endpoints and demographic information, including deidentified individual participant data and a data dictionary defining each field in the set. These data will be made available immediately after publication, with no end date, to researchers who have a signed data access agreement.

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Ethics and Dissemination

This study has received approval from the Ethics Committee of Weifang People's Hospital (approval number: KYLL20250105-5); Chinese Clinical Trial Registry (trial registration number: ChiCTR2500101018). It is being conducted in full compliance with the principles outlined in the Declaration of Helsinki. Informed consent has

been obtained from all participants before their inclusion in the study. Participation in this research does not interfere with routine hospital care, and participants retain the right to withdraw their consent at any time without facing any negative repercussions. Authorship will be attributed to researchers who have made substantial contributions to the study's design, implementation, data analysis, interpretation, and reporting. The results of this study will be disseminated through publication in peer-reviewed academic journals and presentations at relevant conferences.

Consent for publication

Written informed consent for publication was obtained from all individual participants for the publication of their identifiable information.

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Figure.1 Mechanical preparation device and processing procedure for micro-fragmented adipose tissue (MFAT).

Figure.2 Anatomic localization of regions of interest (ROIs) for graft signal-to-noise

quotient (SNQ) measurement.
ROI 1: Intra-/perifemoral tunnel.
ROI 2: Intra-articular graft region.
ROI 3: Intratibial tunnel.
ROI 4: Posterior cruciate ligament reference area.
ROI 5: Anterior to patellar ligament at 2 cm (signal of the background noise).

Table 1. Baseline Characteristics of Participants

Characteristic,median (IQR)	Control Group (n=20)	MFAT Group (n=20)	*P*-value
Age, years	31(22-43)	30 (20-41)	0.43
Sex			0.75
Men(%)	12(60.0)	10(50.0)	
Women(%)	8(40.0)	10(50.0)	
BMI[a]	22.3(20.5-24.9)	22.9(20.3-25.4)	0.53
Operation Time, hours	1.1(1.0-1.2)	1.2(1.0-1.3)	0.02*
Preoperative VAS Score	6(4-7)	5(4-6)	0.22
Preoperative IKDC Score	43(37-61)	45(36-66)	0.73

Abbreviations: BMI, Body Mass Index; VAS, Visual Analog Scale; IKDC, International Knee Documentation Committee

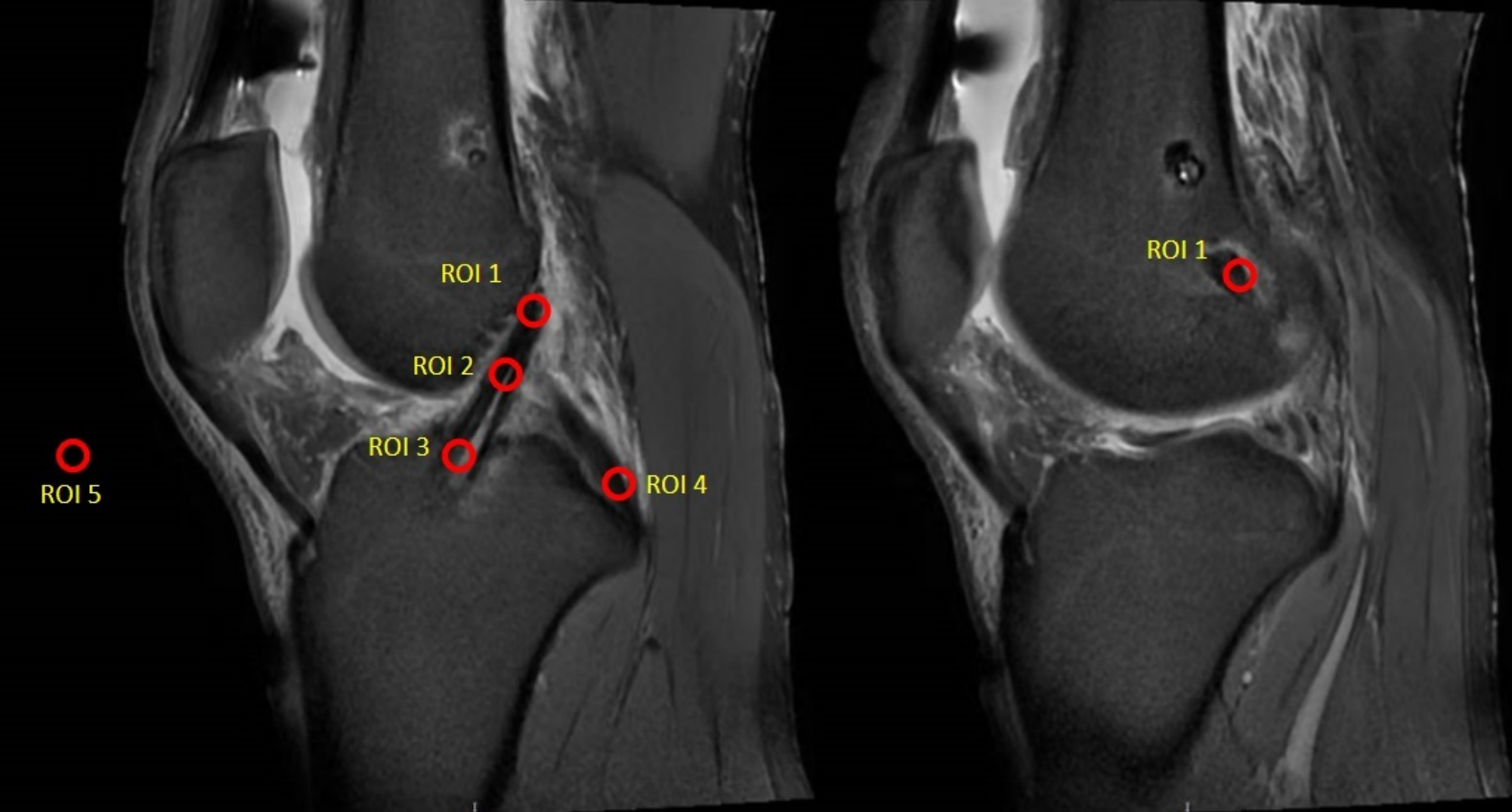
a Calculated as weight in kilograms divided by height in meters squared.

Table 2. Comparison of Primary and Secondary Outcomes Between Groups

Characteristic,median (IQR)	Control Group (n=20)	MFAT Group (n=20)	*P*-value
SNQ - ROI 1	21.3(15.2-33.5)	5(1.3-12.6)	0.00*
SNQ - ROI 2	40.2(22.1-60.8)	35.4(27.3-55.1)	0.75
SNQ - ROI 3	27.6(12.4-38.2)	10.3(4.7-15.4)	0.03*
VAS - 3 months	5(2-7)	3(1-5)	0.04*
VAS - 6 months	3(1-5)	3(1-4)	0.57
IKDC Score - 3 months	57(34-67)	52(28-72)	0.06
IKDC Score - 6 months	69(62-78)	83(68-90)	0.18
Infection, Graft Failure, and Postoperative Bleeding	0	0	

Abbreviations: SNQ, Signal-to-Noise Quotient; VAS, Visual Analog Scale; IKDC, International Knee Documentation Committee


SINGLE USE ONLY
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ROI 1
ROI 2
ROI 3
ROI 4
ROI 5
ROI 1