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RESEARCH

An integrated mechanical–biological approach for early knee osteoarthritis with meniscal tears: combined arthroscopic debridement and stromal vascular fraction injection

Erken dönem menisküs yırtıklı diz osteoartritinde entegre mekanik–biyolojik yaklaşım: artroskopik debridman ve stromal vasküler fraksiyon enjeksiyonunun kombine kullanımı

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Abstract

Purpose: The objective of this study was to evaluate the clinical outcomes of arthroscopic debridement (AD) combined with intra-articular stromal vascular fraction (SVF) injection in patients with early knee osteoarthritis (KOA) accompanied by symptomatic meniscal tears.
Materials and Methods: The present retrospective study comprised 42 knees from 34 patients with Kellgren-Lawrence grade I–II OA who underwent same-session AD and autologous SVF injection. Adipose tissue harvested from the lower abdomen was processed in a closed sterile system to isolate SVF, which was injected intra-articularly following debridement. The severity of pain and the functionality of the affected joints were evaluated using the Visual Analogue Scale (VAS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) before and after surgery.
Results: The mean VAS score improved from 6.07 ± 0.91 preoperatively to 2.12 ± 1.62 at final follow-up (mean reduction: 3.95 points). The mean WOMAC score decreased from 59.50 ± 9.77 to 39.83 ± 12.20 (mean improvement: 19.67 points). Postoperatively, a significant positive correlation was identified between VAS and WOMAC scores, suggesting a potential association between pain reduction and functional improvement.
Conclusion: The combination of AD and intra-articular SVF injection has been shown to result in encouraging clinical outcomes in early KOA with meniscal tears.

Keywords: Arthroscopic debridement, knee osteoarthritis, meniscal tear, regenerative therapy.

Öz

Amaç: Bu çalışmanın amacı, semptomatik menisküs yırtığı eşlik eden erken dönem diz osteoartriti hastalarında artroskopik debridman (AD) ile intra-artiküler stromal vasküler fraksiyon (SVF) enjeksiyonunun klinik sonuçlarını değerlendirmektir.
Gereç ve Yöntem: Bu retrospektif çalışmada, aynı seansta AD ve otolog SVF enjeksiyonu uygulanan Kellgren-Lawrence evre I–II OA tanılı 34 hastaya (42 diz) ait veriler incelendi. Alt abdominal bölgeden elde edilen yağ dokusu kapalı ve steril bir sistemde işlenerek SVF elde edildi ve debridman sonrasında eklem içine enjekte edildi. Ağrı ve fonksiyonel durum, ameliyat öncesi ve sonrası dönemde Vizüel Analog Skala (VAS) ve Western Ontario ve McMaster Üniversiteleri Osteoartrit İndeksi (WOMAC) kullanılarak değerlendirildi.
Bulgular: Ortalama VAS skoru, ameliyat öncesinde 6.07 ± 0.91 iken son kontrolde 2.12 ± 1.62'ye geriledi (ortalama azalma: 3.95 puan). Ortalama WOMAC skoru 59.50 ± 9.77'den 39.83 ± 12.20'ye düştü (ortalama iyileşme: 19.67 puan). Postoperatif dönemde VAS ve WOMAC skorları arasında anlamlı pozitif korelasyon saptandı; bu bulgu ağrı azalmasının fonksiyonel iyileşme ile ilişkili olabileceğini düşündürmektedir.
Sonuç: Artroskopik debridman ile intraartiküler SVF enjeksiyonunun kombinasyonu, menisküs yırtığı eşlik eden erken dejeneratif diz patolojilerinde güvenli ve etkili bir tedavi seçeneği olup, mekanik ve biyolojik iyileşmeyi sinerjik biçimde desteklemektedir.

Anahtar kelimeler: Artroskopik debridman, diz osteoartriti, menisküs yırtığı, rejeneratif tedavi.

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INTRODUCTION

Knee osteoarthritis is a degenerative disorder involving progressive cartilage loss, subchondral bone remodelling, and synovial inflammation. This condition has been demonstrated to result in persistent pain and functional impairment[1,2]. In addition to the age-related degeneration of the joint, mechanical factors, particularly degenerative meniscal injuries, have been identified as significant contributors to the initiation and progression of knee osteoarthritis (KOA). These factors primarily result in altered load distribution, increased focal stress on the articular cartilage, and the induction of mechanical symptoms, joint effusion, and inflammatory responses[3-6]. Arthroscopic debridement (AD) is a procedure that involves the removal of unstable cartilage flaps, fibrillated meniscal tissue, and inflammatory debris. It is regarded as a surgical option of acceptable value for patients with early-stage KOA in conjunction with symptomatic meniscal pathology[7]. However, despite the potential for short-term symptomatic alleviation, AD alone exhibits limited regenerative capacity and does not prevent disease progression[8].

In recent years, there has been an increasing interest in biologic and regenerative strategies as adjuncts to conventional arthroscopic interventions in early KOA. Among these approaches, the use of autologous adipose-derived stromal vascular fraction (SVF) has attracted significant attention due to its minimally invasive preparation and potent regenerative potential. SVF contains a heterogeneous mix of mesenchymal stromal cells (MSCs), endothelial progenitors, pericytes, and macrophages, which collectively exert anti-inflammatory, angiogenic, and chondrogenic effects through paracrine signalling[9,10]. Experimental studies have demonstrated that SVF is capable of modulating the inflammatory microenvironment and enhancing cartilage matrix synthesis. Furthermore, clinical trials have yielded encouraging results, suggesting that intra-articular injection of SVF may alleviate pain and enhance function in cases of mild to moderate KOA[11-13].

Despite the encouraging findings of the previous studies, the majority of these studies have focused on the use of SVF as an intra-articular injection for primary KOA rather than as an adjunct to arthroscopic surgery in patients with concomitant meniscal tears. The mechanical instability and inflammatory environment associated with meniscal injury have the potential to compromise cartilage integrity, thereby reducing the durability of arthroscopic outcomes. Consequently, the application of a biological agent such as SVF immediately following debridement may provide dual benefits by combining the surgical removal of mechanical irritants with a regenerative stimulus that promotes tissue repair. However, the clinical evidence supporting this combined approach in patients with early KOA and concomitant symptomatic meniscal tears is limited[14,15].

In the context of these considerations, the present study was conceived as a preliminary, hypothesis-generating observational investigation with the objective of describing clinical outcomes and safety following combined AD, microfracture in selected cases, and intra-articular SVF injection in patients with early KOA and symptomatic meniscal tears. Due to the implementation of multiple interventions in this study, it was not feasible to attribute clinical outcomes to a specific treatment component.

MATERIALS AND METHODS

Sample

A retrospective screening was conducted on 42 patients (52 knees) who underwent a same-session AD combined with an intra-articular SVF injection for symptomatic KOA at NCR International Hospital, Department of Orthopaedics and Traumatology, between May 2022 and September 2024.

The inclusion criteria for this study were as follows: cases had to meet the Kellgren-Lawrence grade I–II classification for KOA, in addition to a concomitant degenerative meniscal tear, persistent knee pain and/or mechanical symptoms for a minimum period of six months. Furthermore, cases had to demonstrate failure of a minimum of three months of conservative treatment, including non-steroidal anti-inflammatory drugs (NSAIDs), and activity modification.

Since May 2022, patients diagnosed with early KOA and degenerative meniscal tears at our institution have been informed about the option of adjunctive stem cell-based therapy in addition to standard anti-inflammatory drug therapy. The combined mechanical-biological approach was offered to

eligible patients through a shared decision-making process, and written informed consent for the surgical procedure and adjunctive SVF therapy was obtained prior to treatment.

The exclusion criteria comprised BMI > 35 kg/m² (one patient, two knees), traumatic meniscal tears (two patients, two knees), absence of a meniscal tear on arthroscopic evaluation (one patient, one knee), and prior ipsilateral knee surgery or fracture (two patients, two knees). Following a thorough evaluation, it was determined that none of the patients who were included in the study met the exclusion criteria that pertained to inflammatory or rheumatologic disease, pregnancy, or active infection. Patients with a follow-up duration of less than six months (two patients, three knees) were also excluded from the study. Following the application of exclusion criteria, the final study cohort comprised 34 patients (42 knees) (Figure 1).

Procedure

The characteristics of meniscal tears and the extent of compartmental involvement were documented based on arthroscopic findings. All surgical procedures were carried out by a single orthopaedic surgeon with extensive expertise in arthroscopic knee surgery, employing a consistent surgical technique in all cases.

Patient data were obtained retrospectively from archived hospital files and radiological examinations stored within the hospital's Picture Archiving and Communication System (PACS). The integrity and completeness of the records were confirmed by cross-checking clinical documentation with corresponding radiological data prior to analysis.

The Kellgren-Lawrence grading was performed by the first author based on preoperative radiographs[16]. In order to minimise inter-rater variability, the second author reassessed the grading for all patients independently. The intrarater reliability of the grading process was evaluated through the repetition of said process a fortnight after the initial assessments. The reliability of these measurements was then assessed by means of intraclass correlation coefficients (ICCs).

All participants were provided written informed consent for data use in accordance with institutional policy. The study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Sanko University Clinical Studies Ethics Committee (Approval date and number: 2025/07-KAEK-055 / 04).

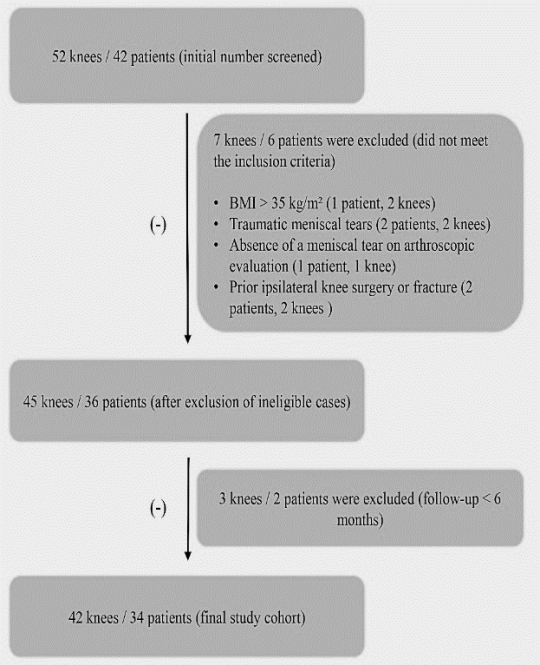

Figure 1. Flowchart illustrating case numbers, exclusion criteria, and final study cohort.

Surgical procedure

The surgical procedure was performed in the supine position under pneumatic tourniquet control and regional anaesthesia with sedation. All interventions were conducted under strict sterile conditions. Standard anteromedial and anterolateral arthroscopic portals were established in order to gain access to the joint. The treatment of meniscal tears involved the utilisation of arthroscopic shavers and punches, with the excision of unstable meniscal tissue. In selected cases, additional cartilage procedures were performed based on intraoperative assessment of lesion severity and morphology. In the presence of such lesions, meticulous debridement was performed to excise unstable cartilage and establish stable margins.

Furthermore, microfracture was performed in six knees (five patients) as a non-routine adjunct. The decision to perform microfracture was made intraoperatively according to the characteristics of the chondral defect, specifically in focal

Outerbridge grade III–IV full-thickness cartilage lesions measuring less than 1 cm in diameter. No additional cartilage intervention was performed in

knees with Outerbridge grade I–II chondral lesions. Following the conclusion of AD and any indicated cartilage procedures, the surgical session continued with the harvesting and preparation of autologous SVF, which was subsequently administered intra-articularly under the same sterile conditions.

Harvesting and intra-articular application of autologous SVF

In the same operative session, autologous adipose tissue was obtained from the subcutaneous tissue of the lower abdomen using a closed, sterile liposuction system (Arthrex® AutoPose™, Arthrex Inc. Naples, FL, USA) (Figure 2a).

Following meticulous sterile preparation and draping, the harvest site was infiltrated with a tumescent solution containing isotonic saline, epinephrine, and 0.25% bupivacaine (Marcaine®, Hospira, Lake Forest, IL, USA). Approximately 200–250 mL of adipose tissue was extracted using gentle negative pressure with a device-compatible harvest cannula, with the objective of minimising mechanical trauma. The lipoaspirate collected was then processed exclusively within the closed Arthrex® system in order to maintain sterility. The aspirate was subjected to repeated washes with sterile phosphate-buffered saline to remove erythrocytes, oil, and debris.

This was followed by gentle mechanical agitation through the device's integrated microsizing mechanism to enhance the release of stromal vascular elements. The purified adipose suspension was then subjected to a centrifugal process at an approximate speed of 430 ×g for a duration of 10 minutes.

This initial centrifugation resulted in the formation of distinct layers comprising oil, adipose tissue, and red blood cells (Figure 2b). The process was then repeated once more to ensure optimal concentration and purity (Figure 2c).

The upper layer was meticulously extracted following each rotation, and the cellular residue was resuspended in sterile saline to yield an injectable suspension of approximately 12–18 mL. The prepared SVF was transferred into a sterile syringe and prepared for intra-articular use (Figure 2d). The suspension was then injected intra-articularly through the superolateral parapatellar portal under strict aseptic conditions following completion of the arthroscopic procedure[13,17].

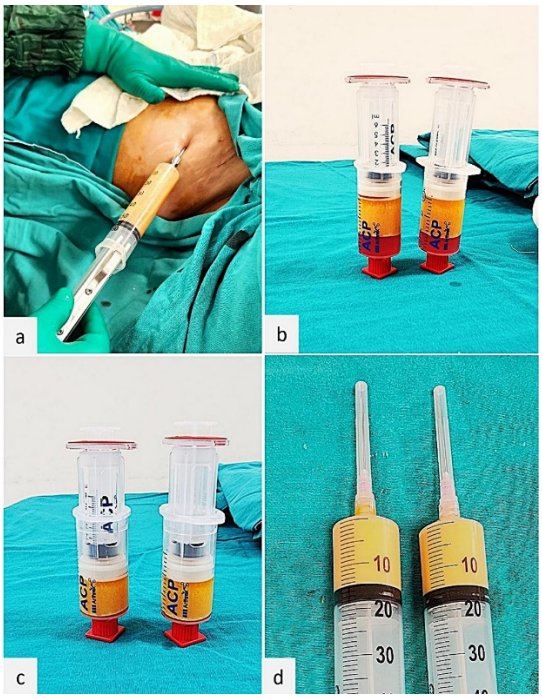

Figure 2. Harvesting, processing, and preparation of autologous SVF.

(a) Closed, sterile liposuction of lower abdominal fat using gentle negative pressure
(b) First centrifugation yielding three layers upper oil, middle adipose (SVF-containing), and lower erythrocyte-rich fraction; oil and RBC layers discarded.
(c) Second centrifugation resulting in two layers an upper compact, SVF-enriched adipose phase and a lower infranatant (residual aqueous/tumescent fluid with minimal debris) that is discarded.
(d) Final sterile SVF suspension for intra-articular injection.

Postoperative period

All patients were permitted early mobilisation and full weight-bearing ambulation as tolerated, beginning four hours postoperatively. Isotonic and isometric quadriceps exercises, in conjunction with active and passive range of motion exercises for the entire lower extremity, were initiated on the first postoperative day without restriction. All patients were discharged the day after surgery. Follow-up assessments were conducted at 3 and 6 weeks postoperatively, followed by evaluations at 3, 6, and 12 months, and subsequently every 6 months thereafter. Suture removal was performed during the 3-week follow-up visit. It was recommended that NSAIDs be avoided

for a period of two weeks following surgery, unless there was a clinical indication for their use.

Outcome assessment

The clinical outcomes were assessed using the Visual Analogue Scale (VAS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC, 0–100; higher = worse). These assessments were conducted preoperatively and at the final follow-up visit. Postoperative complications were systematically recorded and classified based on clinical impact. Major complications were defined as events necessitating surgical reintervention, prolonged hospitalisation, or resulting in permanent morbidity. Conversely, minor complications were defined as self-limiting events managed conservatively.

Statistical analysis

Statistical analyses were performed using SPSS for Windows, version 25.0. The normality of the distribution for continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. A p-value greater than 0.05 in the Shapiro–Wilk test was considered indicative of a normal distribution. The demographic variables of interest, encompassing sex and operated side, were expressed in terms of frequencies and percentages. A descriptive approach was employed to report these data. Continuous variables such as age and follow-up duration were presented as mean ± standard deviation (SD) with minimum and maximum values, and reported descriptively.

The analysis of VAS and WOMAC scores at preoperative and postoperative stages was undertaken to evaluate the clinical changes. As VAS scores did not follow a normal distribution (Shapiro–Wilk p_pre = 0.00034, p_post = 0.00006), a comparison between preoperative and postoperative values was conducted using the Wilcoxon signed-rank test. The distribution of WOMAC scores was found to be normal (Shapiro–Wilk p_pre = 0.216, p_post = 0.203), and the analysis was conducted using the paired t-test.

The correlation between VAS and WOMAC scores in both the preoperative and postoperative periods was assessed using the Spearman rank correlation test. The strength and significance of the relationships were determined by calculating the correlation coefficients (ϱ) and the corresponding p-values. In order to evaluate the consistency of radiological measurements, inter- and intrarater reliability analyses were performed using the intraclass correlation coefficient (ICC). The reliability of the data was classified as follows: poor (<0.5), moderate (0.5–0.75), good (0.75–0.9), or excellent (>0.9). For the purposes of this study, a p-value of less than 0.05 was considered to be statistically significant for all analyses.

A post hoc power analysis was performed using G*Power, based on the observed preoperative–postoperative changes in VAS and WOMAC scores. The analysis demonstrated that, with an alpha level of 0.05 and a sample size of 42 knees, the study achieved a statistical power greater than 0.99 for detecting the observed effect sizes.

RESULTS

The study comprised a total of 34 patients (42 knees) who satisfied the inclusion criteria. The cohort comprised 25 knees from female patients (59.5%) and 17 knees from male patients (40.5%), indicating that several patients underwent bilateral procedures. The mean patient age was 46.2 ± 9.7 years (range, 27–66 years). In 20 cases (47.6%), the operated side was the right knee, while in 22 cases (52.4%), the operated side was the left knee.

With regard to meniscal pathology, tears were observed in the medial meniscus in 32 knees (76.2%), the lateral meniscus in 6 knees (14.3%), and in both the medial and lateral menisci in 4 knees (9.5%). The intraoperative arthroscopic assessment classified all tears as degenerative. The mean follow-up duration was 16.7 ± 7.6 months (range, 6–30 months), ensuring a minimum of six months of postoperative observation for mid-term clinical evaluation (Table 1).

A subsequent analysis of the clinical outcomes revealed significant postoperative improvements. The mean preoperative VAS score was 6.07 ± 0.91 (range, 4.0–8.0), which decreased markedly to 2.12 ± 1.62 (range, 0.0–6.0) at the final follow-up ($p < 0.001$) (Table 1, Figure 3a). Conversely, the WOMAC score exhibited a substantial improvement, decreasing from a preoperative mean of 59.50 ± 9.77 (range, 40–75) to 39.83 ± 12.20 (range, 20–65) ($p < 0.001$) (Table 1, Figure 3b). The findings indicate a consistent reduction in pain and enhancement in functional capacity across the cohort.

No occurrence of major adverse events, such as thromboembolic complications, was observed. Two patients developed superficial wound infections, four exhibited transient joint effusion, and one experienced mild periarticular ecchymosis. It is noteworthy that the management strategy employed was conservative in nature, and this approach was successful in resolving all complications without the occurrence of sequelae.

The correlation analysis between VAS and WOMAC scores is presented in Table 1. In the preoperative period, no significant relationship was found between pain severity and functional limitation (ϱ = –0.044, p = 0.783) (Figure 4a). Conversely, a significant positive correlation was identified postoperatively (ϱ = 0.380, p = 0.013) (Figure 4b).

Prior to the statistical analysis, the inter- and intrarater reliability of the radiographic grading was evaluated in order to ensure consistency. The ICC values demonstrated excellent agreement, with inter-rater ICC = 0.91 (95% CI: 0.85–0.95) and intrarater ICC = 0.93 (95% CI: 0.88–0.96), confirming high measurement reliability.

Table 1. Demographic characteristics, clinical outcomes, and correlation analysis

Variable	**Pre-operative value**		
Sex: M (%) / F (%)	17 (40.5 %) / 25 (59.5 %)		
Age (Years) [Mean ± SD (Range)]	46.2 ± 9.7 (27-66)		
Operated Side			
Right: n (%)	20 (47.6 %)		
Left: n (%)	22 (52.4%)		
Follow-up time (Months) Mean ± SD (Range)	16.7 ± 7.6 (6-30)		
Variable	**Pre-operative value**	**Post-operative value**	**p**
VAS [Mean ± SD (Range)]	6.07 ± 0.91 (4-8)	2.12 ± 1.62 (0-6)	p < 0.001
WOMAC [Mean ± SD (Range)]	59.50 ± 9.77 (40-75)	39.83 ± 12.2 (20-65)	p < 0.001
Correlation between VAS and WOMAC			-
Correlation coefficient (ϱ), p value	- 0.044, 0.783	0.380, 0.013	

M: Male, F: Female, SD: standard deviation, VAS: Visual Analogue Scale WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

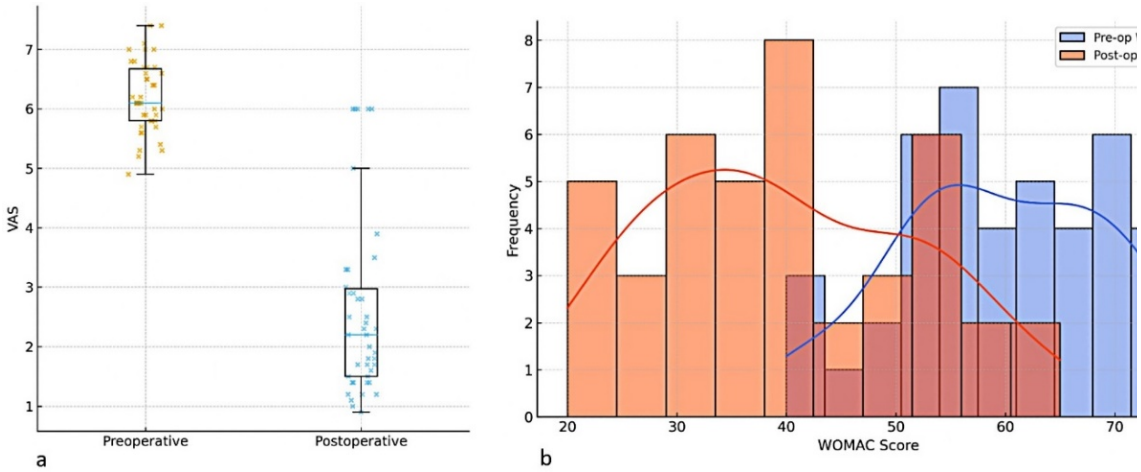

Figure 3. Distribution of preoperative and postoperative VAS and WOMAC scores

(a) Preoperative and postoperative VAS scores, demonstrating a marked reduction in postoperative pain intensity.

(b) Preoperative and postoperative WOMAC scores, showing a leftward shift in postoperative values consistent with functional improvement.

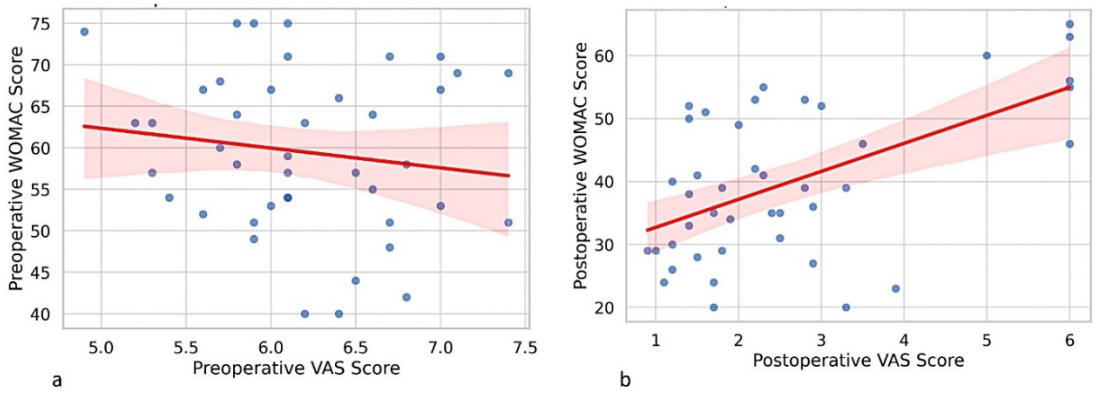

Figure 4. Correlation between pain and function before and after surgery.

(a) No significant relationship was observed between preoperative VAS and WOMAC scores, indicating that pain severity was not associated with preoperative functional limitation.
b) A significant positive relationship was observed between postoperative VAS and WOMAC scores, suggesting that patients with higher postoperative pain tended to exhibit less functional recovery.

DISCUSSION

The present study demonstrated significant improvements in pain and functional outcomes, reflected by marked reductions in VAS and WOMAC scores at final postoperative follow-up. The results of this study suggest that the treatment of early KOA with a combination of AD and intra-articular SVF injection may result in favourable clinical outcomes, with no major complications observed. However, given the retrospective and uncontrolled nature of the study design, the findings should be interpreted as descriptive rather than confirmatory.

As reported in previous studies, the presence of AD in early KOA has been shown to provide pain relief and functional improvement, particularly in knees affected by mechanical irritants such as loose bodies or cartilage flaps[18]. However, purely mechanical interventions have been demonstrated to lack regenerative potential, often resulting in a plateauing or regressing of benefits. It has recently been reported by several clinical studies that isolated intra-articular stem cell therapy (SVF) has produced favourable outcomes in early knee osteoarthritis (KOA). As Aletto et al. observed, significant improvements in VAS and KOOS scores were noted in 123 patients at six months, with no major complications[19]. In a similar vein, Hong et al. reported superior VAS and WOMAC improvements in knees treated with SVF compared with hyaluronic acid controls in a double-blind, randomised trial[20]. Moreover, a recent systematic review confirmed the clinical benefits of SVF therapy, but reported substantial heterogeneity in treatment protocols across studies[21]. The findings of this study suggest that combining arthroscopic interventions with biologic therapies may represent a potentially complementary approach in early degenerative knee disease. However, it should be noted that few studies have evaluated this strategy in a manner comparable to the present study.

In a recent study, Nguyen et al. reported superior improvements in WOMAC and VAS scores in patients treated with a combination of arthroscopic microfracture and adipose-derived SVF and PRP, as compared with microfracture alone[22]. In addition, Koh et al. and Kim Y-S et al. demonstrated significant clinical and imaging-based improvements following arthroscopic procedures combined with SVF in KOA[23,24]. In the present cohort, VAS scores demonstrated a statistically significant decrease from 6.07 ± 0.91 to 2.12 ± 1.62 ($p < 0.001$), while WOMAC scores exhibited a marked improvement from 59.50 ± 9.77 to 39.83 ± 12.20 ($p < 0.001$). These results are consistent with previous findings and may be explained by the complementary mechanisms of action between AD and SVF therapy. In contrast to PRP or HA, the latter of which is largely limited to the release of transient growth factors or viscosupplementation, SVF provides a

heterogeneous cell mix (MSCs, pericytes, immunoregulatory elements) that drives anti-inflammatory signalling, angiogenesis, and extracellular matrix remodelling[21,25]. This dual action, mechanical debridement followed by cellular-driven regeneration, may underlie the sustained functional improvement observed in the present cohort.

Preliminary research indicates that isolated mechanical interventions may offer only a modest enhancement in terms of durability for degenerative knee pathologies. Sihvonen et al. demonstrated that AD for degenerative meniscal tears did not yield superior medium- to long-term outcomes in comparison with placebo surgery. This finding suggests that mechanical treatment alone may be inadequate[26]. Conversely, emerging biologic strategies have demonstrated superior durability in terms of clinical efficacy. In a study by Yokota et al. the effects of intra-articular SVF injection in patients with Kellgren-Lawrence grade II–III KOA were evaluated, and it was reported that there were sustained improvements in pain and functional outcomes over a two-year follow-up, despite the absence of a control group[27]. In accordance with these observations, the cohort under investigation exhibited sustained enhancements in VAS and WOMAC scores over a mean follow-up period of 16.7 months, with no indication of clinical regression. When considered alongside the extant literature, these findings are consistent with the hypothesis that SVF administered as a biological adjunct to AD may contribute to maintaining symptom relief beyond that which might be expected from mechanical intervention alone. However, given the retrospective design and the absence of a control group in the present study, it is not possible to establish causal attribution of the observed clinical benefit to SVF. Consequently, the relative contributions of AD versus SVF injection must be interpreted with caution. Prospective controlled studies will be required to clarify the independent and synergistic effects of these interventions.

Despite the existence of numerous studies that have documented favourable clinical outcomes following intra-articular SVF or MSC-based therapies in cases of KOA, there are also reports of findings that are neutral or inconsistent. Tsubosaka et al. evaluated patients with Kellgren–Lawrence grade I–IV osteoarthritis treated with isolated SVF injections, without any concomitant surgical procedures, and found that, despite symptomatic improvement, MRI-based assessments did not consistently demonstrate structural cartilage restoration[28]. In a similar vein, Sadeghirad et al. conducted a meta-analysis which reported that intra-articular injection of MSCs probably provides minimal to no improvement in pain or physical function[29]. Furthermore, Jeyaraman et al. concluded that there is currently insufficient evidence to support the use of SVF for disease-modifying effects, and that the evidence supporting structural cartilage regeneration remains limited[30]. In contrast, the present study evaluated the administration of SVF in combination with arthroscopic debridement in patients with early-stage osteoarthritis (Kellgren–Lawrence grade I–II), a subgroup that is potentially more responsive to biologic interventions. While these methodological discrepancies may partly explain the favourable clinical outcomes observed, the current evidence does not allow definitive conclusions regarding the long-term efficacy or disease-modifying potential of SVF. Consequently, it is imperative to exercise caution when interpreting the findings of this study. The necessity for further research is evident, in the form of large-scale, well-designed, prospective, randomised controlled trials. Such studies would serve to clarify which patient subgroups derive meaningful benefit from SVF therapy and to determine the true magnitude and durability of its clinical and structural effects.

In the present study, no significant correlation was found between preoperative VAS and WOMAC scores. However, a significant positive correlation emerged postoperatively. Prior to undergoing surgery, the functional capacity of patients suffering from degenerative knee pathologies is influenced by a number of variables. These include, but are not limited to, mechanical impingement, effusion, cartilage lesions and muscle weakness. These factors must be taken into consideration in addition to pain. Consequently, high pain intensity does not necessarily correspond to severe functional limitation, resulting in a weak or absent correlation between VAS and WOMAC scores. Following surgical and biological intervention, many of these confounding factors are mitigated; thus, pain becomes a dominant determinant of function, leading to a stronger postoperative relationship between these parameters. Mehling et al. reported significant improvements in pain and mobility following autologous SVF therapy in 350 patients with knee and hip osteoarthritis[31], findings that are consistent with those from other MSC and SVF-

based KOA studies demonstrating pain–function concordance[32,33].

The present study revealed that no major complications, including deep vein thrombosis, were observed. Despite the potential for thromboembolic events to ensue subsequent to multiple interventions, including knee surgery and liposuction procedures, the adipose tissue harvest in the present study did not entail conventional high-volume liposuction, which is typically employed for body contouring purposes. Conversely, a limited-volume, low-pressure adipose harvest was performed exclusively to obtain an adequate amount of SVF, resulting in a substantially lower procedural burden. When considered in conjunction with relatively brief operative times, expeditious postoperative mobilisation, and the exclusion of high-risk patients (e.g. BMI > 35 kg/m², pregnancy), this may elucidate the absence of thromboembolic events in the present cohort.

The present study was subject to several limitations, including its retrospective design, relatively small sample size, and the absence of a comparative control group treated with either AD alone or SVF alone. A further significant limitation was the absence of standardised radiological follow-up. Consequently, radiographic disease progression or Kellgren-Lawrence stage changes could not be systematically evaluated, which might have provided additional objective support for the clinical outcomes. Furthermore, due to the integrated nature of the intervention, it was not possible to ascertain the specific contribution of each treatment component to the observed minor complications. Furthermore, no detailed cellular characterisation of the SVF product was performed, and variability in SVF composition across patients cannot be excluded.

In conclusion, the combination of AD and intra-articular SVF injection was associated with encouraging improvements in pain and functional outcomes in patients with early KOA accompanied by symptomatic meniscal tears. This combined mechanical-biological approach may represent a potentially beneficial treatment strategy in carefully selected patients. However, given the retrospective uncontrolled design, the simultaneous application of multiple interventions, and the preliminary nature of this case series, no causal inferences regarding treatment efficacy can be made at this juncture. Consequently, these findings should be interpreted with caution and considered hypothesis-generating rather than confirmatory. It is imperative that future prospective randomised controlled studies encompass larger cohorts, longer follow-up periods, and standardised imaging and clinical outcome measures. Such studies are required to validate these preliminary results and to clarify the relative contribution of each treatment component.

Author Contributions: Concept/Design : İHR, NG; Data acquisition: İHR; Data analysis and interpretation: NG; Drafting manuscript: İHR; Critical revision of manuscript: İHR, NG; Final approval and accountability: İHR, NG; Technical or material support:İHR; Supervision: İHR, NG; Securing funding (if available): n/a.
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Consent for publication: Consent for publication was obtained from each participant in this study

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