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Effectiveness of Knee Joint Injury Treatments in the Prevention of Post-Traumatic Osteoarthritis

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by

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Abstract

The purpose of this research and systematic literature review is to determine the effectiveness of rest, physical therapy, and/or surgical intervention following either anterior cruciate ligament (ACL) or meniscus injuries in short- and long- term osteoarthritis outcomes. The short- and long-term outcomes were evaluated to compare the prevalence and progression of osteoarthritis after joint injury. In this literature review, the electronic database PubMed was used to find relevant research. Many keywords were used when searching for articles. Sources included for review had research on ACL or meniscus injuries specifically. Other knee injuries, non-knee injuries and non-human subjects were excluded. Articles involving surgical and/or physical therapy following joint injuries were included, and those involving injectables were excluded. For this review, 11 articles remained. Shown in both short- and long-term research, patients with ACL and meniscus injuries have a high prevalence of post-traumatic osteoarthritis (PTOA). Studies have shown that trialing physical therapy, specifically neuromuscular strengthening exercises, prior to surgical intervention greatly reduces the need for surgery, and that surgical intervention of ACL or meniscus injuries may increase PTOA prevalence due to additional joint injury. In other studies, surgical intervention of ACL injuries with or without formal physical therapy shows advantages in functional outcomes over physical therapy alone. However, patients with meniscus injuries are shown to have better functional and osteoarthritis outcomes when avoiding surgical intervention and opting for physical therapy instead. Determining the best options for patients after knee joint injury should be made on a case-by-case basis until more research can be done to determine the best overall preventative treatment for PTOA.

Keywords: Knee injury and Osteoarthritis Outcome Score, post-traumatic osteoarthritis, knee injury, osteoarthritis, outcomes, conservative treatment, and surgical intervention

Introduction

Knee injuries among athletes, especially those in their youth, have become increasingly common and have unfortunately resulted in long-term consequences. Researchers estimate that around 25-50% of knee injuries will lead to post-traumatic osteoarthritis (PTOA) due to significant inflammation caused by joint trauma (Evers et al, 2022). Today, nearly 27 million American adults ages 25 and over have symptomatic knee osteoarthritis, of which about 5.6 million are associated with PTOA of the lower extremity (Thomas et al., 2017). Patients with PTOA are often burdened by persistent symptoms, reduced mobility, and other life-altering complications due to their injury. To add to this, significant financial costs and work-related time losses are also reported following PTOA. With this in mind, further research is underway to examine the potential preventive effects of common knee joint treatments, to reduce these potential burdens.

New preventive treatments for PTOA are also being researched and are currently in the preclinical phase, but no anti-inflammatory therapies for PTOA are yet available. In the meantime, it is important to understand which available treatments can improve patient outcomes in the long term. This study aims to compare the incidence of post-traumatic osteoarthritis after surgical and conservative treatments to determine if one form of treatment should be indicated over another for the prevention or reduction of the incidence of PTOA.

In at least one of the studies, sham surgeries were used to compare outcomes to actual surgical interventions. Participants in both groups were unaware of which group they were assigned to before, during, and after their procedure. During their surgery while they were under general anesthesia, the surgeon would open the envelope assigned to the patient which would state whether they were to receive actual surgical intervention or a sham surgery. The sham

surgery would go through all of the processes such as going under general anesthesia, entering the operating room, turning tools on that would normally be used, and recovering afterwards in the hospital. However, unlike actual surgery no anatomy would be altered.

Many patient-reported outcome measures were used as assessments in this literature review. The KOOS questionnaire assesses pain, symptoms, quality of life, sport and recreation participation, and activities of daily living. The KOOS scale is from 0 to 100, with lower scores suggesting worse outcomes. The EuroQoL-5D assesses quality of life, including mobility, self-care, usual activities, pain, and mood. The scale is from -0.594 to 1, with one being full health and -0.594 being the worst health. The Tegner Activity Scale is a questionnaire that attempts to numerate a patient's activity level prior to and after an injury. The Medical Outcomes Study 36-Item Short-Form Health Survey looks at the overall health of the patient, such as their physical, mental, and emotional health. The Lysholm knee scoring scale assesses patient symptoms and mobility. The Western Ontario Meniscal Evaluation Tool (WOMET) assesses the patient's quality of life following a meniscal injury. The Fairbank scoring system grades osteoarthritis into five categories (grade 0 is normal and grade 4 has >75% joint space narrowing).

Literature within this report also uses specific objective assessments. The Kellgren and Lawrence system for classification of osteoarthritis assesses anterior-posterior knee radiographs. They have a scoring system of zero to four, in which zero correlates to no presence of osteoarthritis and a four is having severe osteoarthritis. The KT-1000 is an arthrometer that can be used to measure joint motion.

Statement of the Problem

Many patients seek treatment for their osteoarthritic symptoms at their primary care visits. Currently, there are many options to manage symptoms, but none will directly prevent PTOA from developing. It is important to understand which treatments available could slow the progression of PTOA. This review will examine current research on knee joint injury treatments and their short- and long-term effects on patient outcomes.

Research Question

For patients with knee joint injuries, does conservative treatment influence the future risk of post-traumatic osteoarthritis compared to surgical intervention?

Research Methods

A literature review was conducted using the electronic search database PubMed. The search function on the University of North Dakota School of Medicine and Health Sciences Library website was also used to find relevant peer-reviewed journal articles. When searching for relevant articles, keywords such as Knee injury and Osteoarthritis Outcome Score (KOOS), post-traumatic osteoarthritis (PTOA), knee injury, osteoarthritis, outcomes, conservative treatment, and surgical intervention were used. The searches revealed a total of 1,466 articles. The search results were narrowed by excluding research on non-knee related injuries. This literature review focuses on anterior cruciate ligament (ACL) and meniscal injuries due to a lesser amount of research regarding other knee ligament injury outcomes. Thus, articles researching ligament injuries other than the ACL and meniscus were excluded. Studies involving non-human subjects or comparing types of injectables were also excluded. Relevant meta-analyses were not directly

used, although some articles were discovered in their reference sections. The research included in this literature review was not limited to participant age or publication date.

Literature Review

Outcomes of conservative treatment versus surgical intervention on knee joint pathophysiology < 10 years following ACL injury

Ardern et al. (2017) conducted a cross-sectional comparison of patient-reported knee function outcomes between surgically and non-surgically treated anterior cruciate ligament (ACL) injuries. They recruited participants from the Swedish National ACL Registry and issued the KOOS and EuroQoL-5D questionnaires within 180 days of injury and at one, two, and five years post-injury. They gave the questionnaires to participants who did not undergo surgical intervention and those who did undergo ACL reconstruction. To compare the data, the researchers matched individuals from both groups based on age, gender, date of injury, and type of activity played during ACL injury (pivoting versus non-pivoting). There were 879 unique participants, although not every participant completed every follow-up questionnaire increasing the number of participants lost to follow-up. For example, the study had a total of 879 unique participants, but there were only 306 responses for the post-injury follow-up, 350 responses for the 1-year follow-up, 358 for the 2-year follow-up, and 114 for the 5-year follow-up. Fifty-six percent of the participants were male, and the rest were female.

At baseline before treatment, the operative group had significantly higher scores in many categories indicating better outcomes. Their scores were higher than the non-operative group by an average difference of 5.7 points for the KOOS symptoms score, 5.5 points for the KOOS pain score, 4.7 points for the KOOS ADL score, 5.4 points for the KOOS sport and recreation score,

and 0.07 points for the EQ-5D score between groups (all p-values were less than 0.05). There was no significant difference between groups regarding KOOS quality of life and the EQ-Visual Analogue Scale (EQ-VAS) scores.

At the one-year follow-up, the operative group again had significantly higher scores in many categories. Their scores were higher than the non-operative group by an average of four points for the KOOS pain score, 3.4 points for the KOOS ADL score, 12.4 points for the KOOS (sport and recreation), 13.2 points for the KOOS quality of life score, 0.06 points for the EQ-5D score, 7.9 points for the EQ-VAS score between groups (all p-values were less than 0.05). There was no significant difference between groups regarding KOOS symptom scores.

At the 2-year follow-up, the operative group had significantly higher scores in many categories. Their scores were higher than the non-operative group by an average of 4.5 points for the KOOS sport and recreation score, 6.9 points for the KOOS quality of life score, and 6.7 points for the and between groups (all p-values were less than 0.05). There was no significant difference between groups regarding KOOS symptoms, KOOS pain, KOOS ADL, or EQ-5D scores.

At the five-year follow-up, the operative group had significantly higher scores in many categories. Their scores were higher than the non-operative group by an average of 5.3 points for the KOOS symptoms score, 6.8 points for the KOOS quality of life score, 0.09 points for the EQ-5D score, and 6.8 points for the EQ-VAS score between groups (all p-values were less than 0.05). There was no significant difference between groups regarding KOOS pain, ADL, or sport and recreation scores.

The researchers' main conclusion was that patients who chose surgical treatment reported superior quality of life and function in sports. They also had superior knee symptoms, functional outcomes, knee-specific quality of life and health-related quality of life.

The main strength of this research article is the comparison of data from multiple follow-up time points. There are two main weaknesses of this study. First, not all participants answered every follow-up questionnaire, so data could not be tracked for everyone's progression. The other weakness was that the operative group had significantly higher KOOS symptoms, pain, ADL, and sport and recreation scores and significantly higher EQ-5D quality of life scores at baseline before surgical intervention. Higher pre-operative scores could have been why the operative group had higher scores than the non-operative group at subsequent follow-ups.

Frobell et al. (2010) compared outcomes of ACL management over two years. They performed a randomized controlled trial, including 121 participants between the ages of 18 and 35 who had rotational ACL trauma within one month prior to the study. They were split into two groups randomly, which included structured rehabilitation plus early ACL reconstruction and structured rehabilitation with the option of ACL reconstruction later if needed. Sixty-one participants underwent rehabilitation with early ACL reconstruction and 59 were assigned to the rehabilitation plus optional late reconstruction. The researchers assessed the participants at baseline and two-year follow-up using the $KOOS_4$ (pain, symptoms, function in sport and recreation, and knee-related quality of life), Medical Outcomes Study 36-Item Short-Form Health Survey, and the Tegner Activity Scale.

From the optional surgical group, 23 people chose to undergo late ACL reconstruction, and the remaining 36 did not. The improvement in $KOOS_4$ scores from baseline to follow-up averaged 39.2 points for the group having early rehabilitation with optional late reconstruction

and 39.4 points for rehabilitation with early ACL reconstruction. The group difference in KOOS score improvement was -0.2 with a 95% confidence interval (CI) of -6.5 to 6.8 (p=0.96). They concluded that rehabilitation plus early ACL reconstruction did not significantly improve outcomes in young and active adults with acute ACL injuries compared to rehabilitation plus optional late reconstruction. However, the rehabilitation with an optional late ACL reconstruction strategy reduced the frequency of surgical interventions needed in the long term.

The limitations of this study included not having a sham surgery group as a control, non-blinded assessors, and not stratifying results based on activity level. The strengths of this study include multiple assessments and the recency of injury before the study.

Smith et al. (2017) studied the prevalence of osteoarthritis development in professional athletes with previous knee injuries. It was a retrospective study comparing football players' knees via magnetic resonance imaging (MRI) at the 2005-2009 National Football League's Invitational Combine. The researchers wanted to see if the prevalence of knee osteoarthritis was associated with previous knee surgery or their body mass index (BMI). More than 50% of the prospective athletes reported a meniscus and/or ACL injury, and more than 25% had previously undergone surgical intervention. They evaluated 723 knees in total, 144 of which had a previous ACL surgery. The average age of the participants was 22.8, and the average BMI was 31.8. The prevalence of knee osteoarthritis in all previously injured knees was 4%. They found a higher prevalence of knee osteoarthritis in those with a history of previous knee surgery (23% versus 4%, $p < 0.001$). Those with a history of ACL surgery specifically had a knee osteoarthritis prevalence of 24% ($p<0.001$).

Having a BMI > 30kg/m^2 was also associated with an increased risk of osteoarthritis in their previously injured knee regardless of the type of interventions used ($p = 0.007$). They found

no significant difference between player position and the prevalence of knee osteoarthritis. They also had data regarding the meniscus, but that data is discussed later in this literature review.

The strengths of this study include limiting the number of variables by looking at a specific population and involving many years. The limitations of this study include not disclosing how many players had combined ACL and meniscus injuries or surgeries, and they also did not have the dates of the surgeries or injuries of the players.

Outcomes of conservative treatment versus surgical intervention on knee joint pathophysiology ≥ 10 years following ACL injury

Zadehmohammad et al. (2022) conducted a long-term follow-up study comparing the ACL reconstructed knees to their healthy contralateral knee. They aimed to see if individuals would have any long-term effects after joint injury. They evaluated 30 patients with one non-injured knee and one knee that had undergone ACL reconstruction. The average age was 40 years old, and the age range fell between 35-46 years old. The long-term follow-up averaged 16.4 years post-reconstruction, and the range was 13-22 years from surgery. They used Knee injury Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC), Tegner Activity Scale (TAS), and Kellgren and Lawrence (KL) assessments.

The average KOOS score was 92.6 out of 100 at the mid-term follow-up and 89.1 out of 100 at the final follow-up. This finding was significantly different ($p=0.047$). There was a significant difference of $p = 0.031$ regarding the IKDC subjective functional score between mid-term and final follow-ups (9.2 versus 8.4). There was also a significant difference at $p = 0.034$ for compartmental findings and donor site morbidity examined by IKDC. The compartment finding at the mid-term follow-up was 0.1 and at the final follow-up was 0.5.

Regarding the healthy contralateral knee, 86.7% had a normal range of motion. Eighty percent of participants jumped on their injured leg to a height that was at least 90% the height of their healthy leg. The KL assessment showed significant osteoarthritis from mid to final follow-ups in the injured knee compared to the non-injured contralateral knee ($p=0.014$ and $p=0.006$, respectively). They found no significant difference between mid and final follow-ups for the TAS assessment, IKDC function (effusion, motion deficit, one leg hop test categories), IKDC subjective (symptoms, sports and recreation, total percentage categories), and KOOS (symptoms, pain, activities of daily living, sport and recreation and quality of life categories).

They found that patients subjectively remained asymptomatic in the long term based on their KOOS but showed significant osteoarthritis progression compared to their contralateral knee. Only two of the fifteen patients had moderate-severe osteoarthritis in their injured knee.

The main weaknesses of this study included the potential for other ligament injuries, the variations of surgical techniques used, and small sample size. A strength of this study is that the control was the patient's healthy contralateral knee, taking away any differences regarding age, activity level, or genetics.

Meunier et al. (2006) conducted a study looking at the long-term outcomes of surgical and non-surgical treatments in participants with acute and total ACL ruptures. They recruited 100 people under the age of 30 who had a recent unilateral ACL injury. The researchers randomly divided them into groups, including surgical repair with augmentation, surgical repair without augmentation, non-surgical treatment without late reconstruction, and non-surgical treatment initially with late reconstruction. The overall surgically treated group contained 44 patients (33 males and 11 females; mean age of 22; range of 14-30). They underwent surgical repair with or without augmentation methods, followed by an extensive six-week rehabilitation

program. The non-surgically treated group contained 56 patients (35 males and 21 females; mean age 21 range 14-30). Sixteen of those non-surgically treated did have a late ACL reconstruction due to symptomatic instability of the knee. Participants were contacted between 14-19 years post-injury, and were assessed via range of motion, manual stability tests, instrumented stability tests using the KT 1000 arthrometer, Lysholm score, KOOS, Tegner Activity Scale, and radiographic images.

Seventy-six percent of participants who underwent surgical treatment without augmentation had a positive Lachman's test at the follow-up compared to 70% of surgically treated participants with augmentation, 97% of non-surgically treated participants without late reconstruction, and 94% of non-surgically treated participants with late reconstruction ($p=0.02$, surgically treated with augmentation versus non-surgically treated). The percentages of positive pivot shift tests were 24% of surgically treated participants with augmentation, 60% of surgically treated participants without augmentation, 53% of non-surgically treated participants without late reconstruction, and 63% of non-surgically treated participants with late reconstruction ($p=0.035$, surgically treated with augmentation versus non-surgically treated participants). The average distances measured by the KT 1000 (mm) were as follows: 1.7 ± 2.3 for surgically treated participants with augmentation, 2.8 ± 2.6 for surgically treated participants without augmentation, 4.1 ± 3.1 for non-surgically treated participants without late reconstruction, 4.1 ± 2.7 for non-surgically treated participants with late reconstruction ($p=0.0018$, surgically treated with augmentation versus non-surgically treated). The percentages of participants within each group having a KT 1000 greater than 3mm difference were as follows: 31% of surgically treated participants with augmentation, 75% of surgically treated participants without augmentation, 66% of non-surgically treated participants without late reconstruction, 79% of non-surgically

treated participants with late reconstruction (p=0.015, surgically treated with augmentation versus non-surgically treated).

The percentage of participants scoring good or excellent (85-100) regarding the Lysholm score at the 15-year follow-up was 91% of participants surgically treated with augmentation, seven surgically treated participants without augmentation (percentage not given), 75% of participants non-surgically treated without late reconstruction, 88% of participants non-surgically treated with late reconstruction (p=0.118, surgically repaired with augmentation versus non-surgically treated). The mean Lysholm score for surgically treated participants with augmentation and non-surgically treated participants were 95 (range 91-96) and 90 (range 83-92), respectively (p=0.0484).

The KOOS pain averages by groups were 89 for surgically treated participants with augmentation (n=29), 80 for surgical treatment without augmentation (n=6), 88 for non-surgical treatment without late reconstruction (n=31), and 85 for non-surgical treatment with late reconstruction (n=14). KOOS symptoms averages by group were 82 for surgical treatment with augmentation (n=29), 71 for surgical treatment without augmentation (n=6), 85 for non-surgical without late reconstruction (n=31), and 89 for non-surgical treatment with late reconstruction (n=14). KOOS ADL averages by group were 93 for surgical treatment with augmentation (n=29), 92 for surgical treatment without augmentation (n=6), 91 for non-surgical treatment without late reconstruction (n=31), and 90 for non-surgical treatment with late reconstruction (n=14). KOOS sport and recreation averages by group were 70 for surgical treatment with augmentation (n=29), 62 for surgical treatment without augmentation (n=6), 71 for non-surgical treatment without late reconstruction (n=31), and 63 for non-surgical treatment with late reconstruction (n=14). KOOS quality of life averages by groups were 69 for surgical treatment

with augmentation (n=29), 58 for surgical treatment without augmentation (n=6), 64 for non-surgical treatment without late reconstruction (n=31), and 59 for non-surgical treatment with late reconstruction (n=14).

Regarding the Tegner Activity Scale, all groups had a pre-injury level of nine. The median follow-up scores for each group were six for surgical treatment with augmentation, five for surgical treatment without augmentation, six for non-surgical treatment without late reconstruction, and five for non-surgical treatment initially with late reconstruction (p=0.64). The percentages of participants satisfied with their activity level by groups were 84% for surgically treated with augmentation, 50% for surgically treated without augmentation, 75% for non-surgical treatment without late reconstruction, and 69% for non-surgical treatment initially with late reconstruction.

Radiographic images were obtained in extension and 30 degrees of flexion to grade osteoarthritis. The percentages of participants in Kellgren Lawrence grades I-III by groups were 44% of participants surgically treated with augmentation, seven participants surgically treated without augmentation (percentage not given), 48% of participants non-surgically treated without late reconstruction, and 63% of participants non-surgically treated with late reconstruction.

The study concluded that ACL repair did not reduce or increase the risk of osteoarthritis in the long term or increase the subjective outcomes scores, but ACL repair led to less knee instability. The biggest factor that could be identified in determining PTOA outcomes from this article is the status of the participants' meniscus. They thought that early repair of an ACL tear leads to early stabilization of the knee and better functional outcomes.

A disadvantage of this study is that some participants had a secondary ACL treatment after their initial ACL repair due to symptomatic instability. One strength of this study is that they include many participants compared to other similar research, the second is that they include many forms of subjective and objective data.

Outcomes of conservative treatment versus surgical intervention on knee joint pathophysiology < 10 years following meniscus injury

Kise et al. (2016) conducted a randomized controlled trial with two parallel intervention groups comparing knee function outcomes of middle-aged patients with medial meniscal tears. They took 140 participants with medial meniscus injuries and split them into groups undergoing either an arthroscopic partial meniscectomy or exercise therapy. The average age of the participants was 49.5 years old. Ninety-six percent of the participants had no radiologic evidence of osteoarthritis before treatment. Their inclusion criteria were 35-60 years of age, unilateral meniscus tear, a surgical candidate, ability to participate in exercise therapy, and an understanding of Norwegian. They excluded potential participants who had prior knee surgery within the previous two years or if they had a locked knee.

The surgically treated group received arthroscopic partial meniscectomy, and the non-surgically treated group received 12 weeks of supervised exercise therapy. The researchers looked at the differences between changes in injury and $KOOS_4$ (pain, other symptoms, function in sport and recreation, and knee-related quality of life) at baseline and two-year follow-up. They also measured the change in quadriceps and hamstring strength between groups at baseline and three months via physiotherapists using a Biodex 6000 dynamometer. Strength was based on peak torque and total work during knee extension and flexion at 60 degrees per second.

The study-specific cutoff for a clinically relevant difference between $KOOS_4$ scores was 10.1. The KOOS scores showed no significant difference at two years (0.9 points, 95% CI -4.3 to 6.1 p= 0.72). The exercise-only group had an average improvement of 25.3 points at the two-year follow-up, whereas the surgery-only group had an average improvement of 24.4 points. The exercise-only group had significantly more muscle strength at three months than the surgery-only group ($p<0.01$). Nineteen percent of the exercise therapy group later opted for surgery due to subjective knee instability but had no additional benefit according to their assessments.

The differences between treatments were minimal, and the only significant finding was that exercise therapy showed positive effects over surgery alone in improving knee strength in the short term. In their study, they encourage clinicians to educate middle-aged patients with meniscal tears without evidence of osteoarthritis to consider exercise therapy as a treatment option. It may improve function and activity levels regardless of undergoing surgery.

The study's strengths include a randomized controlled trial design, multiple assessments, a high rate of participation at the two-year follow-up, and blinding of the assessors with neoprene sleeves to hide surgery scars. The major limitation of this study included crossover between some of the exercise-only group members to having surgical intervention during the study.

Sihvonen et al. (2013) researched the short-term outcomes of having a meniscectomy compared to sham surgery. They conducted a multicentered, randomized, double-blinded, sham-controlled trial. They included 146 participants aged 35 to 65 with a meniscus tear but without osteoarthritis. In the operating room, individuals were randomly assigned to their respective groups, either undergoing an arthroscopic partial meniscectomy or a sham surgery.

They used Lysholm and Western Ontario Meniscal Evaluation Tool (WOMET) scores to assess the participants at 12 months. Both questionnaires range from zero to 100 (lower scores

indicate poorer outcomes, and higher scores indicate better outcomes). They found that there were no significant changes between groups with either questionnaire. The surgery group had an average Lysholm score improvement of 21.7 points, and the sham surgery group had an average increase of 23.3 points. The difference between groups was -1.6 (95% CI of -7.2 to 4.0). The meniscectomy group had an average WOMET score improvement of 24.6, and the sham surgery group had an average increase of 27.1. The point difference was -2.5 between groups (95% CI of -9.2 to 4.1). The meniscectomy group on average scored a 3.1 for pain after exercise, whereas the sham surgery scored 3.3 on average. The average point difference was -0.2 (95% CI of -0.9 to 0.7). There was also no significant difference between groups in the number of patients requiring subsequent knee surgery after prior treatment. Two in the meniscectomy group and five in the sham surgery group needed subsequent surgical intervention. In conclusion, there were no significant differences in short-term outcomes of medial meniscus tears with or without the procedure.

The strengths of this study included being a randomized controlled trial, having multiple assessments, and using sham surgery as a control. The main limitation of this study included not looking at other types of meniscal tears or other methods of surgical intervention. They also did not use the KOOS or imaging to track osteoarthritis outcomes afterward.

Skou et al. (2018) researched the effects of a 12-week supervised neuromuscular and strengthening therapy program on young adults with a recent meniscus tear. Physical therapists created a specialized plan, which included two weekly exercise sessions lasting between 60 and 90 minutes. They focused on eight neuromuscular and four lower extremity strengthening exercises at each session. They also worked on reducing swelling and improving joint range of motion. They evaluated six adults aged 22 to 39 with MRI-confirmed meniscus injuries who

were eligible for meniscal surgery. They excluded participants with a previous injury in the same knee or a rupture of other ligaments in the same knee. They used the KOOS questionnaire to assess their pain, symptoms, function in daily living, sport and recreation, and quality of life. Participants completed the questionnaire before physical therapy and immediately after finishing the three-month exercise program.

The median improvements (range) for the KOOS questionnaire from baseline to completion of the program were the following: 15 points (0-33) for pain (p=0.06), 11 points (-11 to 50) for symptoms (p=0.60), 16 points (3-37) for function in daily living (p=0.03), 23 points (10-45) for function in sport and recreation (p=0.03), and 9 points (-6 to 31) for quality of life (p=0.22).

The authors' main takeaways were that a neuromuscular and strengthening exercise program for meniscal tears in young adults is feasible, beneficial, and most clinical improvements occurred between the four and ten-week mark of the exercise program. Additionally, six months after the exercise program, participants were asked if they opted to undergo surgical intervention on their meniscus; none had.

Some of the limitations of this study included a participant group of only males with a BMI under 30. In addition, not all participants completed the 24 sessions of the program. The number of exercise sessions completed was self-reported and not confirmed with the physical therapists. They did not compare data to non-injured knees. The sample size was small, with six participants. The study's strengths were excluding prior knee injuries and additional injuries of other knee ligaments.

Krych et al. (2016) researched the five-year outcomes of non-operative management of medial meniscus posterior root tears (MMPRTs). They also looked at risk factors for worse outcomes. They performed a retrospective review on participants with confirmed symptomatic unrepaired MMPRTs. They conducted a two-year follow-up assessing International Knee Documentation Committee (IKDC) outcome scores, Tegner scores, and radiographs. Radiographs were also collected initially and at a minimum of two years following diagnosis. The authors defined the failure of this study as needing arthroplasty or having severely abnormal patient subjective IKDC scores. There were 52 participants (21 male and 31 female) with an average age of 58. They were followed for an average of 62 months. The study used chi-square, Wilcoxon rank-sum, and Kaplan-Meier analyses to compare outcome scores, progression, and rates of late arthroplasty to age, gender, and BMI.

Sixteen out of 52 patients needed total knee arthroplasty at an average of 30 months after receiving the diagnosis of MMPRTs. The average IKDC score for the 36 remaining participants was 61.2. Females scored significantly lower than males, 75 versus 49 ($p=0.01$). The average Kellgren-Lawrence grades and arthritic rates worsened over time on radiographs from baseline at 1.5 to 2.4 at follow-up ($p<0.001$). There was significantly more grade 2+ osteoarthritis at the final follow-up (78%) compared to baseline (51%) ($p=0.01$). According to the study's failure definition, 87% of the patients failed non-operative treatment, which included 16 patients undergoing arthroplasties and 29 having severely abnormal IKDC scores. The remaining seven participants who did not qualify for having a failed outcome all had abnormal IKDC scores and progression of osteoarthritis on radiographs. They did not find a significant association between BMI and any specific outcome of the study. Lastly, they found that higher Kellgren-Lawrence grades of osteoarthritis were associated with increased arthroplasty rates ($p=0.01$). In conclusion,

non-operative repair of MMPRTs had a higher likelihood of poor clinical function, increased arthroplasty rates, and worsened arthritis of the knee at the five-year follow-up.

The study's limitations included the trial type being a retrospective study that lacked comparative baseline scores. They did not assess the outcomes of those undergoing surgical intervention during the study, and they only looked at a few variables for potential risk factors for worsened outcomes. The study's strengths included a large panel of participants, and they assessed their participants subjectively and objectively. Another strength was narrowing the inclusion criteria to a specific injury, such as the medial meniscus posterior horn tear.

As discussed in the short-term outcomes of ACL treatment, Smith et al. (2017) studied the prevalence of osteoarthritis development in professional athletes after knee injuries and surgeries. It was a retrospective study comparing football players' knees via MRI at the 2005-2009 National Football League's Invitational Combine. As a reminder, the overall prevalence of knee osteoarthritis in their studied population was 4%. They found a higher prevalence of knee osteoarthritis in those with previous knee surgery (23% versus 4%, $p < 0.001$). In addition to finding a significant difference in those with a history of ACL surgeries, they also discovered that those with a history of meniscus surgery had a knee osteoarthritis prevalence of 27% ($p<0.001$).

Outcomes of conservative treatment versus surgical intervention on knee joint pathophysiology ≥ 10 years following meniscus injury

Aprato et al. (2021) researched arthroscopic meniscectomy outcomes in patients 20 years post-operation. It was a retrospective study that included 225 patients aged 18-50. The participants were 71.1% male, 4% were under the age of 20, 20.4% were between 20-30 years

old, 23.5% were between 30-40 years old, and 52% were older than 40 years old. They included participants who had undergone a partial, subtotal, or total meniscectomy. Previously diagnosed advanced osteoarthritis was the main exclusion criterion.

They looked at the outcomes after 20 years and investigated associated predictors of poor clinical results, such as age at surgery, gender, knee alignment, amount of meniscus resected, rate/timing of total knee replacement, and KOOS scores. Ten patients required a total knee replacement in the 20-year follow-up period. The average time from arthroscopic meniscectomy to needing a total knee replacement was seven years (standard deviation of 3.87). The 20-year conversion rate to a total knee arthroplasty rate after meniscectomy was 4.4%. They compared benchmark data of KOOS subscale scores of being equal or superior to age and gender and found that the overall percentage of poor outcomes for pain was 15%, for symptoms was 10.6%, for ADL was 16%, for sport and recreation was 13.3%, and for quality of life was 6.2%. No p-values were given for these statistics. Significant predictors of poor outcomes requiring a total knee replacement included age between 40-50 ($p < 0.01$), malalignment ($p < 0.01$), and lateral or total meniscectomy (both, $p < 0.01$). Other predicting factors resulting in poor KOOS scores include age between 40-50 years of age at the time of surgical intervention ($p < 0.01$), female sex ($p < 0.01$), malalignment ($p = 0.04$), and a total meniscectomy ($p = 0.04$).

The strengths of this study include involving a wide range of participant age and only including those with isolated meniscus injuries. This study's limitations include being a retrospective study lacking a control group. There was a lack of pre-operative KOOS scores and periodic questionnaires to evaluate differences at other time intervals. No other assessments outside of KOOS were evaluated, for example, radiographic evidence of osteoarthritis.

Stein et al. (2010) researched the long-term difference in outcomes between partial meniscectomies and meniscal repairs after a traumatic meniscal tear. They included 81 participants. Forty-two individuals had a meniscal repair (16 women, 26 men; average age of 31.29) and 39 had a partial meniscectomy (12 women, 27 men; average age of 32.54). They evaluated their participants based on Lysholm and Tegner scores. They also assessed the knees radiologically and gave them a Fairbank score based on osteoarthritic progression. The radiographs were compared to the participants' healthy contralateral knees. The researchers also compared pre-operative sports activity level and age at which surgery was completed. The long-term follow-up ranged from 6.21 - 11.45 years.

They found that 80.8% of those undergoing meniscal repair did not show signs of osteoarthritis progression at follow-up compared to 40% after meniscectomy ($p = 0.005$). The difference between Fairbank scores of the meniscal repair group prior to surgery and at follow-up was -0.19 and -0.6 ($p = 0.005$). The preinjury activity level was maintained post-operatively in 96.2% of the meniscal repair group and 50% of the meniscectomy group ($p =0.001$). The functional score revealed no significant difference between the two surgical treatments at follow-up ($p = 0.114$).

The strengths of this study include a functional comparison of the injured knee to their healthy contralateral knee. The weaknesses of this study include non-randomized surgical treatments, not including non-surgical treatment as a variable, and an imbalance between the quantity of males and females.

Discussion

The topic of osteoarthritis following knee joint injury treatments is not a heavily researched one. However, studies are beginning to compare the functional short and long-term effects of physical therapy and surgical intervention on injured joints. ACL and meniscal injuries were specifically looked at in this report as research was more readily available on them compared to other joint injuries, and since the research on this topic is relatively new and upcoming, there are only a few studies that directly use x-rays to confirm or deny the presence of osteoarthritis in their participants. Instead, most studies use a variety of different assessments to evaluate a knee's functional status besides x-rays. Nonetheless, the information included in these studies can still give insight into the overall outcome of the knee joint after certain treatments.

The articles within this report that studied the short-term effects of ACL injury treatments did not come to a consensus on whether surgical or non-surgical treatments significantly affected osteoarthritis outcomes. Adern et al. (2017) discovered that patients who underwent surgical treatment for ACL injuries had significantly better scores regarding the quality of life, function in sports and recreation, knee symptoms, and knee-specific quality of life than those who did not. Frobell et al. (2010) found that rehabilitation with early ACL reconstruction did not significantly improve outcomes in active young adults with acute ACL injuries compared to rehabilitation with optional late reconstruction. However, they concluded that offering rehabilitation first with optional late reconstruction significantly decreased the number of surgical interventions undergone in the long term. Smith et al. (2017) concluded that in their population of professional athletes, there was a significantly greater prevalence of radiograph-confirmed osteoarthritis in players with a history of ACL surgery compared to those who did not undergo surgical

intervention. They also found that athletes with an elevated BMI of > 30 kg/m^2 had worsened osteoarthritis outcomes regardless of surgical intervention or not.

The articles that studied the long-term effects of ACL injury treatments also did not come to an overall conclusion on whether surgical intervention following ACL injuries influenced long-term outcomes. Zademohammad et al. (2022) discovered that patients who underwent ACL reconstruction remained subjectively asymptomatic at the long-term follow-up based on their KOOS assessments. However, they concluded that there was a significant osteoarthritis progression after ACL surgery compared to their non-injured contralateral knee. Meunier et al. (2006) found that ACL repair did not reduce or increase the risk of osteoarthritis in the long term, and ACL repair did not increase the subjective scores either. They concluded that ACL repair improves the injured knee's stability, leading to early stabilization and better subsequent functional outcomes.

On the efficacy of non-surgical versus surgical, articles that studied the short-term effects of meniscal injury treatment did not find an overarching conclusion either. Kise et al. (2016) found minimal difference between medial meniscal repair and exercise therapy in the short term. However, exercise therapy significantly improved knee strength over surgery alone. Sihvonen et al. (2013) found no significant short-term differences between groups undergoing meniscal surgeries and those undergoing sham surgeries. There was also no significant difference between the groups regarding the number of subsequent surgeries needed after initial treatment. Skou et al. (2018) saw significant improvements with neuromuscular and strengthening exercises, and no patients elected to have meniscal surgery six months following the exercise program. Krych et al. (2016) stated that 87% of patients failed the non-operative treatment according to the study's criteria and did not find a significant difference between outcomes and BMI. They concluded

that non-operative treatment of MMPRTs has a likelihood of poor clinical function, increased arthroplasty rates, and worsened arthritis of the knee at the five-year follow-up.

Likewise, the articles that studied the long-term effects of meniscal injury treatment did not come to a consensus. Smith et al. (2017) discovered a higher prevalence of osteoarthritis in professional athletes if they had undergone meniscus surgery versus conservative treatment. Aprato et al. (2021) found significantly worse KOOS assessments in patients that underwent meniscectomies compared to the public. Their analysis concluded that predictors of poor outcomes were associated with ages between 40-50, malalignment, lateral or total meniscectomy, and female sex. Stein et al. (2010) stated that 80.8% of those undergoing meniscal repair did not show signs of osteoarthritis progression at follow-up compared to 40% with meniscectomy. In addition, meniscal repair showed better functional outcomes than meniscectomy.

There can be many things to consider when looking at the reliability of these studies. Having data at baseline prior to treatment can show progress, decline, or stability of participants' functionality and osteoarthritis. Smith et al. (2017) and Krych et al. (2016) did not include comparative data, which does not directly indicate if the surgery, rigorous activity, or joint injury caused increased osteoarthritis prevalence. Another key factor regarding reliability is including multiple forms of assessment. Frobell et al. (2010) evaluated their participants using the $KOOS_4$, Medical Outcomes Study 36-Item Short-Form Health Survey, and the Tegner Activity Scale. Meunier et al. (2006) assessed subjectively and objectively using manual stability tests, instrumented stability tests, Lysholm score, KOOS, Tegner Activity Scale, and radiographic images. This allows researchers to look at a bigger picture of the participants' condition, reduce the amount of skewed data, and compare the data to other studies using the same assessment. Another important factor regarding reliability is comparing a participant's injured knee to their

non-injured knee. Stein et al. (2010) did this, eliminating many variables in the data, such as activity level and age, as the knees are from the same person. Sihvonen et al. (2013) blinded the patients via a sham surgery option, and Kise et al. (2016) blinded the assessors with neoprene sleeves, which allowed the study to reduce any treatment bias. Some studies included multiple follow-ups, which enables the ability to graph participants' progression over time rather than just before and after comparisons, as seen in Adern et al. (2017).

One factor that reduces reliability is not having good follow-up participation. It is difficult to compare data when participants are not consistently assessed at every follow-up, as seen in Adern et al. (2017). Another factor that would reduce reliability is if one group has significantly higher baseline scores than the other. It may skew the end data because if both groups improved at the same rates, the group starting with significantly higher scores would end with significantly higher scores too, which was seen in Adern et al. (2017).

Between all four themes, there was not an exact answer to whether surgical treatment or conservative therapy improved knee outcomes significantly more than the other in the short or long term. Each study analyzed different variables, including populations, treatment types, and injuries. In most of the studies in this report, surgical intervention of the ACL showed benefits to the function and stability of the knee joint, while surgical intervention of the meniscus showed worsened functional scores. One concept that stayed consistent throughout was the benefit of a neuromuscular exercise program. Many studies that evaluated it found that either exercise therapy alone or in conjunction with surgical treatment improved functional outcomes. That said, there is room for future studies to investigate this topic further. One of the major gaps in current research is the lack of radiographic evidence of osteoarthritis, so many researchers are relying on subjective questionnaires to predict future outcomes. To narrow this gap, future studies could

explore the accuracy of scores to actual confirmed cases of PTOA. Comparing functional scores to radiographic evidence of osteoarthritis over a longer period and including multiple types of knee injuries in one report to compare may also be productive, as different injuries may benefit from different types of treatment. Researchers could also compare the outcomes of the timing of surgical intervention and the length of physical therapy participation. Because there are not a lot of specific osteoarthritis measurements in the short term, it would be important to compare functional assessments to radiographic osteoarthritis to ensure there is a correlation between them. There are additional conservative therapies for knee joint injuries and osteoarthritis, such as injectables. However, the scope of this review was to compare the variables of surgery versus physical therapy or rest. Future studies could compare the use of injectables, such as monoclonal antibodies, steroids, and hyaluronic acid.

Conclusion

In the current literature, there are still discrepancies in terms of short- versus long-term outcomes of surgical and non-surgical treatments of knee injuries, as both have benefits and risks. Trialing physical therapy exercises first before surgical intervention greatly reduced the need for surgery in some studies and offered great results with neuromuscular strengthening exercises. Other studies show that surgical patients had better short- and long-term functional and symptomatic outcomes than non-surgical patients. However, some studies showed that patients who underwent surgical intervention of ACL or meniscal tears had an increased incidence of radiograph-confirmed osteoarthritis afterward.

There are many areas of research that can still be investigated regarding PTOA outcomes. Future studies could look at the results following other non-surgical treatments and the timing of surgery after injury. Additional long-term studies, using radiographs as objective evidence of

osteoarthritis, would strengthen current research. Lastly, continued research and development of preventive agents will be a major step forward in improving care for patients with knee injuries and the prevention of PTOA.

Application to Clinical Practice

Primary care providers often see patients seeking treatment for knee osteoarthritis. There are many management options, but there are still no treatments for PTOA prevention yet. Therefore, this literature review examined current research to evaluate the short and long-term outcomes of patients following surgical and non-surgical treatments for knee injuries.

When discussing treatment options with patients with knee injuries, it is important to consider the type of injury, the severity of the injury, the previous level of activity, the age of the patient and their overall health. The decision between treating conservatively versus surgically should be a joint decision between the patient and provider, after educating the patient on potential risks and benefits of each option. The current literature lacks a consensus on using a particular treatment to prevent post-traumatic osteoarthritis. Thus, the patient's treatment decision should continue to surround symptomatic relief and mobility improvement until further research can be carried out or new treatments become available.

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