Journal Pre-proof

Medial Collateral Ligament Pie-Crusting for Isolated Medial Meniscal Root Repair is Associated with Improved Clinical Outcomes with Minimum 2-Year Follow-Up

Agustin P. Herber, DO, Joseph C. Brinkman, MD, Sailesh V. Tummala, MD, Kostas J. Economopoulos, MD

PII: S0749-8063(23)00595-9

DOI: https://doi.org/10.1016/j.arthro.2023.07.029

Reference: YJARS 58642

To appear in: *Arthroscopy: The Journal of Arthroscopic and Related Surgery*

Received Date: 28 September 2022

Revised Date: 17 July 2023

Accepted Date: 18 July 2023

Please cite this article as: Herber AP, Brinkman JC, Tummala SV, Economopoulos KJ, Medial Collateral Ligament Pie-Crusting for Isolated Medial Meniscal Root Repair is Associated with Improved Clinical Outcomes with Minimum 2-Year Follow-Up, *Arthroscopy: The Journal of Arthroscopic and Related Surgery* (2023), doi: https://doi.org/10.1016/j.arthro.2023.07.029.

Medial Collateral Ligament Pie-Crusting for Isolated Medial Meniscal Root Repair is Associated with Improved Clinical Outcomes with Minimum 2-Year Follow-Up

Agustin P. Herber[1] DO, Joseph C. Brinkman[2] MD, Sailesh V. Tummala[2] MD, Kostas J. Economopoulos[2] MD

[1] University of Arizona College of Medicine Phoenix, Phoenix, Arizona, U.S.A.
[2] Department of Orthopedic Surgery, Mayo Clinic, Phoenix, Arizona, U.S.A.

Corresponding Authors:
Kostas J. Economopoulos MD email: Economopoulos.kostas@mayo.edu; Phone number: 480-301-8351; Address: Mayo Clinic Department of Orthopedic Surgery: 5881 E Mayo Blvd, Phoenix, AZ 85054 Building 2

Joseph C. Brinkman MD; email: Brinkman.Joseph@mayo.edu; Phone number: 602- 403-9077; Address: Mayo Clinic Department of Orthopedic Surgery: 5881 E Mayo Blvd, Phoenix, AZ 85054 Building 2

Sailesh V. Tummala MD; email: tummala.sailesh@mayo.edu; Address: Mayo Clinic Department of Orthopedic Surgery: 5881 E Mayo Blvd, Phoenix, AZ 85054 Building 2

Agustin P. Herber DO; email:herberag@arizona.edu; Address: Mayo Clinic Department of Orthopedic Surgery: 5881 E Mayo Blvd, Phoenix, AZ 85054 Building 2

IRB: Study 1322973; IRB 20216101

Medial Collateral Ligament Pie-Crusting for Isolated Medial Meniscal Root Repair is Associated with Improved Clinical Outcomes with Minimum 2-Year Follow-Up

ABSTRACT

Purpose

The purpose of this study was to determine clinical and radiographic outcomes of medial collateral ligament (MCL) pie-crusting during isolated medial meniscal root repair.

Methods

A retrospective review was conducted between August 2013-December 2019 in patients undergoing isolated medial meniscal root repair. Outcomes including International Knee Documentation Committee (IKDC) score, Lysholm score, re-tears, MCL laxity, and conversion to total knee arthroplasty (TKA) were compared between pie crust (PC) and non-pie crust (NPC) cohorts. Other assessments included subjective instability or stiffness, infection, and intra-operative chondromalacia. Additionally, radiographic outcomes were compared to determine progression of medial compartment arthrosis.

Results

Final analysis included 97 knees, 45 in the PC and 52 in the NPC group. IKDC and Lysholm scores were similar between both groups preoperatively and 3 months postoperatively. However, at the 6,12 and 24-month follow up, the PC group had a significantly higher measured IKDC and Lysholm scores than the NPC group. PASS percentages for the IKDC score were significantly higher in the PC group at 6-months, 1-year and 2-years (96.2% p=0.02) follow-up compared to the NPC group. MCID percentages for the IKDC score were also significantly higher at the 1- and 2-year (100% p=0.05) follow-up in the PC group compared to the NPC group. There was also a significantly higher rate of recurrent medial meniscal root tears in the NPC group (4

(8.9%)) compared to the PC group (0 (p=0.03)). No MCL laxity was observed at 6 months follow up.

Conclusion

MCL pie-crusting during isolated medial meniscal root repair can be utilized as an alternative surgical technique as it leads to improved clinical and patient outcomes compared to patients who do not undergo MCL pie-crusting in the short-term. Additionally, those that underwent MCL pie-crusting had a lower incidence of recurrent tears and no patients experienced MCL laxity at 6 months.

Level of Evidence: Level 3 retrospective cohort/comparative study

INTRODUCTION:

The meniscus serves an important role in joint stability, load transmission, and shock absorption in order to maintain overall function of the knee. With the meniscal roots anchoring the menisci to the tibial plateau, the menisci function to convert axial tibiofemoral loads into hoop stresses[1-4] to reduce compressive loads on the knee and prevent meniscal extrusion outside the joint[1,2]. Therefore, to prevent excess loading and chondral cartilage breakdown, the integrity of the meniscal root on the tibial plateau must be preserved[2].

Meniscal root tears are defined as radial tears within 1 cm of the meniscal root attachment or soft tissue or bony root avulsion injuries[1-4]. When injured, the meniscus fails to convert axial loads into transverse hoop stresses and the abnormal load transmission leads to decrease tibiofemoral contact area and increase contact pressures accelerating cartilage degeneration. Additionally, injury to the posterior root leads to significantly more medial meniscal displacement and gap formation at the avulsion site when an axial load is applied at the knee.[2] This may contribute to medial meniscus extrusion causing considerably impaired transmission of hoop stresses and higher peak contact pressures in the weight bearing surfaces of the joint accelerating development of medial compartment knee osteoarthritis (OA)[1-4].

Previous studies have suggested that tears of the posterior root of the medial meniscus account for 10-30% of all medial meniscal tears treated arthroscopically[1,2,5] with posterior root radial tears occurring in 27.8%[5] of cases reported by Lee et al. Previous treatment options that provided short term benefits include total or partial meniscectomy.[3] But recent studies elucidated that repair of full thickness meniscal root tears can restore tensile hoop stresses, joint congruence, meniscal integrity, and normal function of the knee preventing progression of arthrosis.[4,7] However, arthroscopic repair techniques are technically demanding and require excellent visualization to address meniscal pathology, especially at the posterior portion of the knee. In knees with tight medial compartments, posterior meniscal lesions are often difficult to visualize and characterize tear configuration due to a narrow medial joint space. Subsequently, attempts at repairing the meniscal pathology in the setting of a tight medial compartment or varus knee can lead to iatrogenic cartilage injury because of limited visibility and working space[7-9,] . While manipulation of the knee under valgus stress may help open the narrow joint space, the surgeon must be aware of unwanted complications MCL rupture or femur fracture.[7,9]

Pie-crusting of the medial collateral ligament (MCL) is a technique described in both TKA and meniscal repairs and involves repetitive percutaneous fenestrations of the ligament with a needle while a valgus stress is applied to the knee to facilitate visualization of the medial joint line. This surgical technique has been shown to be advantageous for repairs of meniscal pathologies in that it allows improved visualization of the posterior horn of the meniscus with a decreased incidence of iatrogenic chondral damage[7-16]. MCL lengthening has shown to be safe in clinical situations such as meniscal repair, partial meniscectomy, and TKA, [7, 8, 13,16, 17] however, there are limited reports discussing the clinical effects of MCL pie-crusting in medial meniscal root repairs.[7, 14, 16-18] The purpose of the present study is to determine the clinical and radiographic outcomes of MCL pie-crusting during isolated medial meniscal root repair. We hypothesized that pie-crusting the MCL during posterior horn medial meniscal root repair does not affect the clinical outcome or rate of complications.

METHODS:

A retrospective review was performed on prospectively collected data on a consecutive series of patients undergoing isolated posterior horn medial meniscal root repair at a single academic institution by a single sports medicine fellowship-trained surgeon (K.J.E.), from August 2013 until December 2019, after the surgeon implemented pie crusting as apart of their practice . Institutional review board approval was obtained from the author's home institution. Inclusion criteria included those patients undergoing an isolated posterior medial meniscal root repair using a transtibial approach who had 2 or more years of follow-up. Exclusion criteria included those patients undergoing anterior root or lateral meniscal root repair; concomitant procedures such as ligament reconstruction, cartilage procedures or osteotomies, previous procedures to the knee, and those with Kellgren-Lawrence (K-L) grade 3 or 4 changes on preoperative standing radiographs or Grade 4 chondromalacia in the medial or lateral compartment at the time of arthroscopy as assessed by the Outerbridge score. Leg alignment was assessed clinically. If any suspicion for greater than 5 degrees of varus or valgus, the patient was not included in the study. Finally, patients who did not have 2-years or more of follow up were excluded from the study. Those included in the study were separated into two groups depending on if they underwent MCL pie-crusting (PC group) or did not have MCL pie-crusting (NPC group).

Patient Characteristics:

Chart review was performed by research coordinators associated with the study to obtain demographic information including age, sex, BMI and side of the procedure. It was also documented whether the tear was associated with trauma (acute tear) or more degenerative in nature. Preoperative magnetic resonance imaging (MRI) reports were reviewed by surgeon

(K.J.E) to determine the amount of medial meniscal extrusion, which has been described as the distance from the outer margin of the extruded meniscus to the outer margin of the articular cartilage of the ipsilateral tibial plateau on coronal MR imaging.[1]. Major extrusion was considered 3mm or more of extrusion.

Preoperative Workup:

Patients were selected for meniscal root repair based on their clinical history and MRI findings. In patients with chronic medial sided knee pain, six weeks of conservative therapy were attempted prior to surgical treatment including anti-inflammatories, activity modifications, physical therapy and a steroid injection. Some patients attempted bracing and assistive walking devices, but these were not mandatory to proceed to surgery. If patients did not have relief of their pain after six weeks conservative treatment, had Kellgren-Lawrence scores of 2 or lower, or an MRI that was consistent with a full-thickness radial tear of the meniscal root tear they were offered surgery to correct their tear. In those patients who described an acute traumatic event, surgery was offered acutely without requiring them to fail 6 weeks of conservative treatment. However, all patients were offered conservative options.

Surgical Technique:

All posterior medial meniscal root repairs were performed in the same fashion. Diagnostic arthroscopy was performed using anteromedial and anterolateral portals to visualize patellofemoral (PF), medial, and lateral compartments. The amount of PF, medial, and lateral joint chondromalacia was noted, but shaving chondroplasty was not performed per the surgeon's typical practice. Once all compartments were evaluated, the knee was placed back on valgus stress to help fully visualize the medial compartment. The decision whether to perform MCL pie-crusting was dependent on visualization of the posterior medial meniscal root at the time of arthroscopy. If the capsular attachment just superior to the posterior horn of the medial meniscus could be visualized, then the MCL was not pie-crusted. However, if the posterior medial meniscal root or capsular attachment superior to the posterior horn was not visualized, the MCL was pie-crusted to allow better visualization. Accordingly, pie-crusting was performed consistently throughout the study timeline rather than on a practice-change basis.

Pie-crusting was performed with a technique consistent accordance with previous reports[19]. While the leg was placed in valgus stress, an 18-guage needle was used to create several percutaneous fenestrations in the proximal MCL. Under direct arthroscopic visualization. the medial joint space increased as the MCL was progressively elongated, however, complete MCL release was avoided. Typically, pie-crusting was considered adequate once the entire posterior capsule, just above the posterior horn and meniscal root of the medial meniscus was easily viewed.

A shaver was then placed through the anteromedial portal to debride scar tissue from the medial edge and posterior root of the meniscus. After debridement, the Arthrex Passport (Naples, FL, United States) was placed into the anteromedial portal. 0-Fiberlink (Arthrex, Naples, FL, United States) was then placed through the center of the medial meniscus roughly 1 cm lateral to the meniscal root using a Meniscal Scorpion (Arthrex, Naples, FL, United States). A luggage-tag stitch was then created and pulled out through the anteromedial Passport. A second 0-Fiberling was then placed in the meniscal root about 0.5 cm from the edge using the Meniscal Scorpion

(Arthex, Naples, FL, United States). To assist in this, the previously placed stitch is put on tension to pull the posterior horn and meniscal root anteriorly. Again, a luggage-tag is created and pulled back through the anteromedial Passport. An ACL guide was then placed in the center of the posterior meniscal root footprint. A small incision made on the anterior-medial cortex and a 6-mm Arthrex Flipcutter (Naples, FL, United States) drilled into the center of the footprint. Once the Flipcutter was confirmed to be in the center of the meniscal root footprint, the Flipcutter was deployed and a10-mm deep socket created. Next, a Fiberstick (Arthrex, Naples, FL, United States) was placed up through the tibia and through the socket created. The suture from the Fiberstick was then grasped and brought out the Passport. The two previously placed luggage-tag sutures were then shuttled through the socket and down the drilled tunnel bringing the sutures out the anteromedial cortex of the tibia. The knee was then placed in full extension and the posterior meniscal root visualized. Tension was then placed on the both stitches bringing the most medial end of the meniscus into the drilled socket. Once appropriate tension and seating of the meniscus into the socket, the anterior cortex of the tibia was drilled and tapped for an Arthrex 4.75mm Swivellock anchor (Arthrex, Naples, FL, United States). The two luggage-tag sutures which were placed through the medial aspect of the meniscus were then attached to the Swivellock and the anchor placed into the drill hole and screwed in while the tension on the meniscus is visualized arthroscopically. Once secured, the meniscus was probed to confirm appropriate tension. The incisions were then closed and sterile dressing applied to knee. A T-Scope brace locked in extension was then placed on the patient.

Postoperative Care and Rehabilitation:

Postoperative protocols were identical between the groups. The patient was allowed to be toe-touch weightbearing for the first 10 days locked in extension with the use of a walker or crutches. After their first post-operative visit at 10 days, the brace was unlocked from 0-90 degrees which it remained for 4 weeks. At two weeks, patients started physical therapy to work on passive range of motion (ROM) to 90 degrees and quad strengthening. Toe-touch weightbearing was maintained until six weeks postoperatively. At this time, patients were able to discontinue the brace, wean off the crutches, and increase knee flexion and weight bearing as tolerated.

Clinical and Patient Reported Outcomes:

Each patient was asked to fill out International Knee Documentation Committee (IKDC) Subjective Knee Form and Lysholm surveys prior to being scheduled for surgery. Patients were then asked to fill out both surveys at the 3, 6, 12 and 24-month follow ups by a research coordinator. If patients did not show up for their scheduled post-operative visits, they were emailed the survey to fill out. Reminder emails and phone calls were made by the same research coordinator. Clinical significance after arthroscopic posterior medial meniscal root repair was quantified using the distribution-based Minimal Clinically Important Difference (MCID) and anchor-based Patient-Acceptable Symptomatic State (PASS) for the IKDC score.[20] The threshold value that corresponded to achieving a clinically significant outcome of MCID for IKDC was 10.9 while the threshold PASS for IKDC was 69.0[20].

In terms of clinical outcomes, MCL laxity was determined by physical exam preoperatively, 6 weeks, 12 weeks and 6 months after surgery by the surgeon (K.J.E). Laxity was graded as ‘0’ with no opening; ‘1’ for minimal opening (1mm); ‘2’ for moderate opening (2mm) and ‘3’ for significant opening (3mm or more). Other clinical outcomes included recurrent tear of the medial meniscal root as diagnosed on repeat MRI, conversion to total knee arthroplasty, subjective feeling of instability or stiffness, rate of infection, and Outerbridge score to assess intra-operative chondromalacia.

Radiographic Outcomes

Each patient had preoperative plain standing radiographs of the knee. The imaging was repeated at the 6-month, 1-year and 2-year follow-up. The 2-year and preoperative medial compartment K-L grades were compared to each other to determine the amount of progression of medial compartment arthrosis.

Statistics:

Statistics were performed using SPS-X. Continuous data was compared using two-tailed unpaired student-T test while categorical data was calculated using Chi-square analysis. A p-value of 0.05 was set as significant.

RESULTS:

Of the 149 meniscal root repairs performed, 97 isolated medial meniscal root repairs in 90 knees were included in the final analysis. The NPC and PC cohorts were comprised of 45 and 52 knees, respectively (Figure 1). Demographic information specific to mean age, BMI, and sex for the PC and NPC group are outlined in Table 1. In the present study, although posterior meniscal root tears were not classified as described by LaPrade et al, all were Type 2 complete radial tears. Traumatic injuries made up 28.9% and 25% of the NPC and PC group injuries respectively (p=0.67).

The level of chondromalacia in all 3 compartments was similar between the groups (Table 1). Preoperative imaging showed similar arthrosis of the medial compartment between the two groups. At final follow-up, there was no difference between the groups with regards of arthrosis progression (Table 2). Preoperative MRI showed no difference between the groups with respect to the amount of extrusion of the meniscus. The average amount of extrusion was 2.7 mm for the NPC group and 2.9mm for the PC group (p=0.14). Major extrusion (3 mm or more) was identified in 84.4% of the NPC group and 90.4% of the PC group (p=0.38).

Preoperative IKDC and Lysholm scores were similar between the two groups preoperatively (Table 3). Both groups had significant increases in both the IKDC and Lysholm scores over preoperative values for all postoperative time points throughout the study. IKDC scores were shown to be similar at 3 months and then found to be significantly higher at the 6 month, 1-year and 2-year follow-up (85.1; p=0.002) in the PC cohort when compared to the NPC group (78.7 at 2 years). PASS percentages for the IKDC score were similar at 3-month follow up and significantly higher in the PC group at 6-month, 1-year and 2-year (96.2%; p=0.02) follow up compared to the NPC group (82.2% at 2-years). MCID percentages for the IKDC score were similar at 3 and 6-months then were significantly higher at the 1- and 2-year (100% p=0.05) follow-up in the PC group compared to the NPC group (93.3% at 2-years) (Table 4). The Lysholm scores showed a similar pattern as the IKDC scores. There was no difference between the two groups at the 3 month follow up but at the 6 month, 1 and 2 year (84.1; p=0.01) follow ups, the PC group had significantly higher scores compared to the NPC group (79.0 at 2-years).

NPC group had a significantly higher rate of recurrent meniscal root tears than the PC group (Table 2). There were 4 (8.9%) meniscal root re-tears in the NPC group compared to no re-tears in the PC group (p=0.03) as diagnosed on MRI. Conversion to TKA, performed by a fellowship trained arthroplasty surgeon, occurred in 8.9% of the NPC group and 3.9% of the PC group (p=0.31). Results for MCL laxity at 6 weeks, 12weeks, and 6 months are shown in Table 2. Of the observed in 29 knees in the PC group at 6 weeks follow up, 15 (28.9%) experienced grade 1, 8 (15.4%) had grade 2, and 6 (11.5%) demonstrated grade 3 laxity. MCL laxity persisted in 4 (7.7%) knees at 12 weeks with 2 (3.9%) having grade 1 and 2 (3.9%) demonstrating grade 2 laxity. However, no laxity was observed in any knees at 6 months follow up. There was no difference between the two group with regards to knee stiffness, defined as range of motion deficit requiring manipulation or arthroscopic debridement. There was also no difference in the rate of superficial or deep infection requiring antibiotics or repeat surgery. Two patients in each group developed symptomatic arthrofibrosis requiring manipulation under anesthesia and lysis of adhesions.

DISCUSSION:

This study showed that pie-crusting during isolated primary medial meniscal root repairs led to improved early patient outcomes compared to patients who did not undergo pie-crusting. Beginning at the 6-month postoperative period, both IKDC and Lysholm scores were significantly higher in the pie-crusting group than the non-pie-crusting group. In addition, the percentage of patients achieving PASS and MCID for the IKDC score were significantly higher in the PC group compared to the NPC group at the 6- and 12-month time points respectively. Likewise, the Lysholm scores were significantly higher in the PC group beginning at the 6-month time point. Retear rates were significantly higher in the NPC group in the short term follow up. The rate of other complications were similar between the two groups.

Select prior studies have evaluated the outcomes of pie crusting the MCL in arthroscopic procedures. Gaudiani et al. 2020, conducted a systematic review to identify outcomes and complications after percutaneous superficial MCL (sMCL) lengthening to address isolated medial meniscal pathology. Of the sixteen studies reviewed, four were identified to meet inclusion criteria. The report included 192 total patients that had percutaneous superficial MCL (sMCL) lengthening, of whom 76% underwent meniscectomy (146/192) whereas meniscal repair was performed in 24% (46/192) of cases [8, 9, 13,16, 17]. This systematic review reported no perioperative complications such as iatrogenic chondral damage, fracture, or incidence of saphenous vein or nerve injury. At final follow up, minimal residual joint laxity was noted on valgus stress test, however, no subjective instability or postoperative complications were observed [8,9,13,16,17]. A retrospective review of 60 patients completed by Han et al. 2020 evaluated the outcomes of percutaneous pie-crusting of the posteromedial complex (PMC) of the knee performed during arthroscopic medial meniscal meniscectomy or repair. Results from the study showed a statistically significant difference in joint space width (JSW) between preoperative and first week postoperative measurements, however, no significant differences in JSW were observed 3 months after surgery when compared to the preoperative baseline and patients did not have subject or objective medial join instability[21]. Additional findings from the study demonstrated significant differences in postoperative patient reported outcomes (ie. VAS, Lysholm, IKDC, Tegner scores) when compared to preoperative scores.[21] Moran et al. 2020 conducted a prospective review of 42 patients that underwent arthroscopic partial medial meniscectomy with sMCL pie-crusting. Outcomes data collected at the 6 week follow up visit found statistically significant increases in PROMIS and IKDC scores as well as radiographic and clinical resolution of iatrogenic laxity[22]. In a study conducted by Zhu et al. 2017, 32 patients were evaluated after undergoing knee arthroscopy for posterior horn medial meniscal tears with a mean follow up period of 28 months (24, 36 months). The findings from the study demonstrated an insignificant difference with respect to medial JSW at 3 months postoperatively and statistically significant increases in functional outcomes (ie. VAS, Lysholm, IKDC, Tegner) scores at final follow up[18].

Although there are studies that report significant differences in patient reported outcomes after MCL lengthening during arthroscopic medial meniscal procedures, we found superior outcomes past the 6 month follow up time point in cases of isolated meniscal root repair. Further, we report rate of achieving clinical significance, which was superior in the pie crusting group beginning at 6 months for the PASS score and 1 year for the MCID score in relation to IKDC outcomes. Taken together, pie crusting the MCL during arthroscopic knee procedures appears to offer at minimum a non-inferior result when compared to cases without pie crusting. This may be explained by improved visualization that affords better assessment and subsequent management of any present pathology.

Medial tenderness and valgus instability due to MCL laxity are specific concerns with disrupting the native MCL. Few studies have evaluated these outcomes in the setting of MCL lengthening. In our study, we found no signs of laxity after the 6 months follow up. This lack of laxity may be explained by only an incomplete release of the MCL until appropriate visualization was established. Our results also did not demonstrate an increased progression of arthritis, conversion to TKA, or other complications. Accordingly, previous reports in addition to ours would suggest that pie crusting the MCL for medial compartment opening is a safe procedure does not reliably increase the rates of laxity, instability, or other complications.

LIMITATIONS

There were several limitations noted in this study. The study design was non-randomized and retrospective in nature without a true control group or a priori power analysis. It is possible the groups had different levels of pathology. This makes the study prone to selection bias as well as recognized confounding variables. The treating surgeon was also not blinded while taking radiographic measurements. Further, the study did not include assessment of iatrogenic cartilage damage, postoperative knee pain, or independent assessment of the outcomes. Additionally, data utilized came from a relatively small sample size followed with short term follow up. Longer follow up would assist understanding of the true rate of conversion to knee replacement between the groups.

CONCLUSION:

MCL pie-crusting during isolated medial meniscal root repair can be utilized as an alternative surgical technique as it leads to improved clinical and patient outcomes compared to patients who do not undergo MCL pie-crusting in the short-term. Additionally, those that underwent MCL pie-crusting had a lower incidence of recurrent tears and no patients experienced MCL laxity at 6 months.

Group characteristics

	NPC group (n=45)	**PC group (n=52)**	**p**
Age (mean± SD)	57.2 ± 8.5	55.2 ± 10.9	0.328
BMI (mean± SD)	30.5 ± 5.0 kg/m^2	31.5 ± 7.1 kg/m^2	0.343
Sex (% Female)	77.8	75.0	0.751
Laterality (% Right)	46.7	50.0	0.746
Traumatic Tear (%)	28.9	25.0	0.670
Major meniscal extrusion (%)	84.4	90.4	0.381
Kellgren-Lawrence			
Grade 1 (%)	42.2	46.2	0.701
Grade 2 (%)	57.8	44.2	0.187
Outerbridge Score			
Medial compartment (mean± SD)	2.0 ± 0.7	1.9 ± 0.8	0.715
Lateral compartment (mean± SD)	0.9 ± 1.0	1.0 ± 0.8	0.591
PF compartment (mean± SD)	2.1 ± 1.1	2.3 ±1.1	0.439

Table 1. Comparison of demographic and pre-operative information between Non-Pie-Crusting (NPC) and Pie-Crusting (PC) cohorts. Statistics were performed using Chi-square analysis for categorical data. The asterisk (*) represents a statistically significant difference between the two groups. P-value of .05 was set as significant. (PF = patellofemoral; BMI= body mass index; SD=standard deviation)

Clinical Outcomes

	NPC group (n=45)	**PC group (n=52)**	**p**
K-L Grade 3 Progression, n(%)	9 (20)	13 (25)	0.618
K-L Grade 4 Progression, n(%)	3 (6.7)	4 (7.7)	0.848
Meniscal extrusion (mm)	2.7	2.9	0.140
Recurrent tears, n(%)	4 (8.9)	0	0.028*
Stiffness, n(%)	2 (4.4)	2 (3.9)	0.884
Conversion to TKA, n(%)	4 (8.9)	2 (3.9)	0.309
Infection, n(%)	2 (4.4)	1 (1.9)	0.480

MCL Laxity n (%)			
Post op 6 weeks	0	29 (55.7)	0.00000005*
Post op 12 weeks	0	4 (7.7)	0.058*
Post op 6 months	0	0	0

Table 2. Comparison of Non-Pie-Crusting (NPC) and Pie-Crusting (PC) Group clinical outcomes. The asterisk (*) represents a statistically significant difference between the two groups. P-value of .05 was set as significant. (TKA = total knee arthroplasty)

Postoperative outcome scores

	NPC Group	PC Group	P
IKDC (mean± SD)			
Pre-operative	41.7 ± 9.1	44.2 ± 9.4	0.184
3-month post-operative	64.6 ± 9.0	62.4 ± 9.9	0.262
6- month postoperative	74.8 ± 6.7	80.5 ± 6.8	<0.005*
1-year post-operative	76.4 ± 12.4	83.3 ± 9.8	0.003*
2-years post-operative	78.7 ± 11.5	85.1 ± 8.2	0.002*
Lysholm (mean± SD)			
Pre-operative	44.6 ± 8.4	46.9 ± 8.4	0.192
3-month post-operative	62.0 ± 7.4	61.4 ± 8.6	0.713
6- month postoperative	72.7 ± 6.3	76.8 ± 7.5	0.005*
1-year post-operative	80.0 ± 7.3	84.5 ± 9.1	0.008*
2-years post-operative	79.0 ± 9.1	84.1 ± 9.6	0.010*

Table 3. Comparison of Non-Pie-Crusting (NPC) and Pie-Crusting (PC) Group IKDC and Lysholm scores preoperatively, 3, 6, 12, and 24 months postoperatively. Statistics were performed using two-tailed student-T test for continuous data. The asterisk (*) represents a statistically significant difference between the two groups. P-value of .05 was set as significant. (IKDC= International Knee Documentation Committee; SD=standard deviation)

Rate of achieving MCID/PASS

	NPC Group	PC Group	p
PASS			
% 3 months	35.6%	25.0%	0.26
% 6 months	82.2%	98.1%	0.006*
% 12 months	75.6%	96.2%	0.002*
% 24 months	82.2%	96.2%	0.02*
MCID			
% 3 months	86.7%	84.6%	0.77
% 6 months	97.8%	98.1%	0.92
% 12 months	91.1%	100%	0.03*
% 24 months	93.3%	100%	0.05*

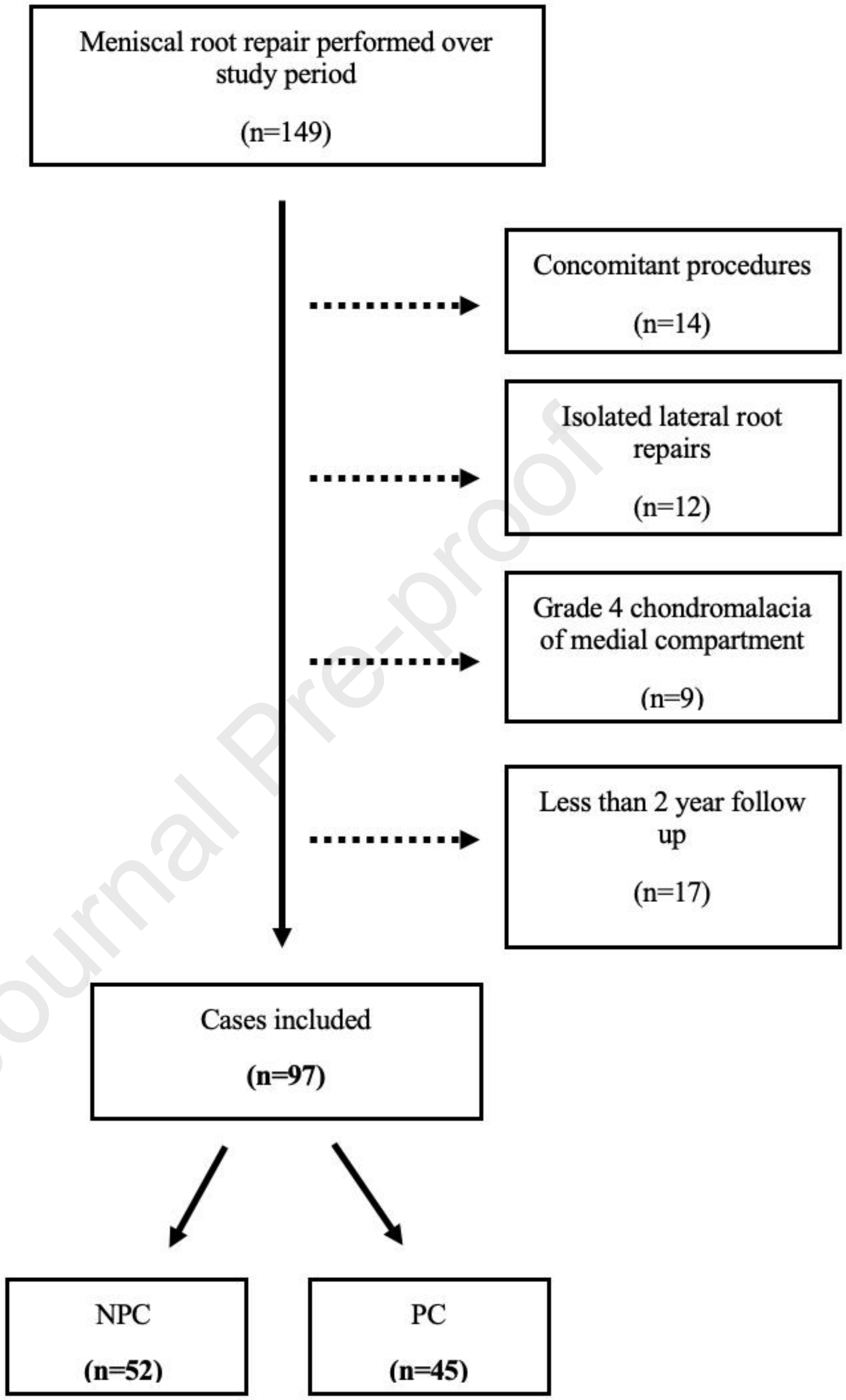
Table 4. Rate of achieving MCID or PASS for subjective IKDC score in Non-Pie-Crusting (NPC) and Pie-Crusting (PC) Groups at 3, 6, 12, and 24 months postoperatively. The asterisk (*) represents a statistically significant difference between the two groups. P-value of .05 was set as

significant. (PASS-Patient-Acceptable Symptomatic State; MCID- Minimal Clinically Important Difference; IKDC= International Knee Documentation Committee)

REFERENCES

1. Banovetz MT, Roethke LC, Rodriguez AN, LaPrade RF. Meniscal Root Tears: A Decade of Research on their Relevant Anatomy, Biomechanics, Diagnosis, and Treatment. Arch Bone Jt Surg. 2022 May;10(5):366-380.
2. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. Am J Sports Med. 2014 Dec;42(12):3016-30.
3. Pache S, Aman ZS, Kennedy M, Nakama GY, Moatshe G, Ziegler C, LaPrade RF. Meniscal Root Tears: Current Concepts Review. Arch Bone Jt Surg. 2018 Jul;6(4):250-259.
4. Moatshe G, Chahla J, Slette E, Engebretsen L, Laprade RF. Posterior meniscal root injuries. Acta Orthop. 2016 Oct;87(5):452-8.
5. Lee DW, Ha JK, Kim JG. Medial meniscus posterior root tear: a comprehensive review. Knee Surg Relat Res. 2014 Sep;26(3):125-34.
6. Bin SI, Kim JM, Shin SJ. Radial tears of the posterior horn of the medial meniscus. Arthroscopy. 2004 Apr;20(4):373-8.
7. Chung KS, Ha JK, Ra HJ, Kim JG. Does Release of the Superficial Medial Collateral Ligament Result in Clinically Harmful Effects After the Fixation of Medial Meniscus Posterior Root Tears? Arthroscopy. 2017 Jan;33(1):199-208.
8. Claret G, Montañana J, Rios J, Ruiz-Ibán MÁ, Popescu D, Núñez M, Lozano L, Combalia A, Sastre S. The effect of percutaneous release of the medial collateral ligament in arthroscopic medial meniscectomy on functional outcome. Knee. 2016 Mar;23(2):251-5.
9. Gaudiani MA, Knapik DM, Kaufman MW, Salata MJ, Voos JE, Karns MR. Percutaneous Superficial Medial Collateral Ligament Release Outcomes During Medial Meniscal Arthroscopy: A Systematic Review. Arthrosc Sports Med Rehabil. 2020 Jan 19;2(2):e153-e159.
10. Chernchujit B, Gajbhiye K, Wanaprasert N, Artha A. Percutaneous Partial Outside-In Release of Medial Collateral Ligament for Arthroscopic Medial Meniscus Surgery With Tight Medial Compartment by Finding a "Magic Point". Arthrosc Tech. 2020 Jun 9;9(7):e935-e940.
11. Polat B, Aydın D, Polat AE, Gürpınar T, Sarı E, Özmanevra R, Yalçınozan M, Erler K. Objective Measurement of Medial Joint Space Widening with Percutaneous "Pie Crust" Release of Medial Collateral Ligament during Knee Arthroscopy. J Knee Surg. 2020 Jan;33(1):94-98.
12. Todor A, Caterev S, Nistor DV. Outside-In Deep Medial Collateral Ligament Release During Arthroscopic Medial Meniscus Surgery. Arthrosc Tech. 2016 Jul 25;5(4):e781-e785.
13. Fakioglu O, Ozsoy MH, Ozdemir HM, Yigit H, Cavusoglu AT, Lobenhoffer P. Percutaneous medial collateral ligament release in arthroscopic medial meniscectomy in tight knees. Knee Surg Sports Traumatol Arthrosc. 2013 Jul;21(7):1540-5.

14. Park YS, Moon HK, Koh YG, Kim YC, Sim DS, Jo SB, Kwon SK. Arthroscopic pullout repair of posterior root tear of the medial meniscus: the anterior approach using medial collateral ligament pie-crusting release. Knee Surg Sports Traumatol Arthrosc. 2011 Aug;19(8):1334-6.
15. DeFroda SF, Singh H, Cohn MR, Vadhera AS, Verma NN. Meniscal Root Repair With Mini-Open Medial Collateral Ligament Release. Arthrosc Tech. 2021 Nov 9;10(11):e2571-e2575.
16. Jeon SW, Jung M, Chun YM, Lee SK, Jung WS, Choi CH, Kim SJ, Kim SH. The percutaneous pie-crusting medial release during arthroscopic procedures of the medial meniscus does neither affect valgus laxity nor clinical outcome. Knee Surg Sports Traumatol Arthrosc. 2018 Oct;26(10):2912-2919.
17. Lons A, Boureau F, Drumez E, Pasquier G, Putman S. Does medial collateral ligament pie-crusting induce residual laxity in arthroscopic management of medial meniscus tears? A prospective study of 40 cases. Orthop Traumatol Surg Res. 2018 Sep;104(5):707-711
18. Zhu W, Tang Q, Liao L, Li D, Yang Y, Chen Y. [Application of pie-crusting the medial collateral ligament release in arthroscopic surgery for posterior horn of medial meniscus in knee joint]. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2017 Sep 28;42(9):1053-1057. Chinese.
19. Erdem M, Bayam L, Erdem AC, Gulabi D, Akar A, Kochai A. The Role of the Pie-Crusting Technique of the Medial Collateral Ligament in the Arthroscopic Inside-out Technique for Medial Meniscal Repair With or Without Anterior Cruciate Ligament Reconstruction: A Satisfactory Repair Technique. Arthrosc Sports Med Rehabil. 2020 Dec 26;3(1):e31-e37.
20. Maheshwer B, Wong SE, Polce EM, Paul K, Forsythe B, Bush-Joseph C, Bach BR, Yanke AB, Cole BJ, Verma NN, Chahla J. Establishing the Minimal Clinically Important Difference and Patient-Acceptable Symptomatic State After Arthroscopic Meniscal Repair and Associated Variables for Achievement. Arthroscopy. 2021 Dec;37(12):3479-3486.
21. Han X, Wang P, Yu J, Wang X, Tan H. Arthroscopic pie-crusting release of the posteromedial complex of the knee for surgical treatment of medial meniscus injury. BMC Musculoskelet Disord. 2020 May 14;21(1):301.
22. Moran TE, Demers AJ, Shank KM, Awowale JT, Miller MD. Percutaneous Medial Collateral Ligament Release Improves Medial Compartment Access During Knee Arthroscopy. Arthrosc Sports Med Rehabil. 2020 Dec 27;3(1):e105-e114.



(NPC= Non Pie-crusting Cohort; PC=Pie Crusting Cohort)
Figure 1. Patient flow chart diagram