KNEE EVIDENCE NOTES · 2026

Protect, preserve, restore the knee

A handout from three lectures: the evidence, the numbers and the practical messages, for athletes, coaches and clinicians.

1 **Sports injury prevention**
Six domains, what works, ACL prevention and making it stick

2 **Alignment, meniscus and stability before cartilage**
Why cartilage surgery fails when biomechanics are ignored

3 **Meniscus repair: 5 pearls**
Selection, planning, technique, rehabilitation and the unhappy repair

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OMKNEEHEALTH LONDON

Holistic knee care, personalised.

About this handout

These notes accompany three lectures given by Chinmay Gupte in 2026. They summarise the key evidence and the practical messages in a form you can keep, share and come back to.

Sports injury prevention 1

What works, what does not, and how to build an ACL prevention programme that athletes will actually do.

Alignment, meniscus and stability before cartilage 2

Why cartilage surgery fails when the mechanics of the knee are ignored, and how to plan around them.

Meniscus repair: 5 pearls 3

Selecting, planning, performing and rehabilitating a meniscus repair, and managing the repair that goes wrong.

Who it is for

- **Athletes, parents and coaches:** each part starts with key messages and a plain-language box.
- **Physiotherapists, sports medicine doctors and surgeons:** the detailed sections give the numbers, the study types and the references.

How to read the numbers

- **Relative risk reduction** tells you how much a programme lowers the chance of injury compared with not doing it. "40% fewer injuries" means 6 injuries instead of 10 in a similar group.
- **Number needed to treat** is how many people must do something for one of them to benefit.
- **Laboratory and cadaver studies** explain mechanisms. They do not prove that a treatment works in patients. These notes say which type of study each figure comes from.
- Effects found in one group, for example female footballers or military recruits, may not apply to every athlete.

IMPORTANT

This handout is for education. It is not personal medical advice and does not replace an assessment by a qualified clinician. If you have a knee injury or symptoms, please see a doctor or physiotherapist. The evidence is summarised as it stood in November 2026 and will change as new studies appear.

Contents

Part	Topic
1	Sports injury prevention: six domains, what works, ACL prevention, making it stick
2	Alignment, meniscus and stability before cartilage: load, root tears, osteotomy, combined surgery
3	Meniscus repair: 5 pearls, from patient selection to the unhappy repair
	About the author, Sportshealing and OmKneeHealth London

PART ONE

I Sports injury prevention

Strength, balance, load, sport-specific training, metabolism and movement: what the evidence supports, with a focus on the knee.

KEY MESSAGES

1. Many sports injuries can be prevented. Exercise-based programmes typically cut injuries by about a third or more.
2. Strength training gives the largest single effect. Stretching on its own does not prevent injury.
3. Structured neuromuscular warm-ups reduce ACL injuries in female athletes by about 61%.
4. Match training load to capacity. Sudden spikes in load raise the risk of injury.
5. A programme only works if it is done. Athletes who complete most sessions get the benefit.

IN PLAIN LANGUAGE

Getting stronger, practising balance, landing and changing direction well, and building up training gradually all reduce injuries. A 15 to 20 minute warm-up, done two or three times a week through the whole season, is one of the most effective things a team can do. Stretching alone, knee braces and instructional videos do not prevent injuries.

Six connected domains

Injury risk depends on many things acting together, so prevention works best when several domains are trained at once.

Strength and conditioning

The strongest single effect. In meta-analyses, strength training cut sports injuries by about two-thirds, and more training volume gave more protection.

Balance and proprioception

Reduces ankle sprains by about a third, most clearly after a previous sprain. Balance work alone does not protect the knee.

Load management

Rapid changes in training, competition, travel or psychological load raise injury risk. Prescribe load, then monitor the response.

Sport-specific training

Programmes built for the sport work best. The FIFA 11+ warm-up reduced football injuries by about a third.

Metabolic optimisation

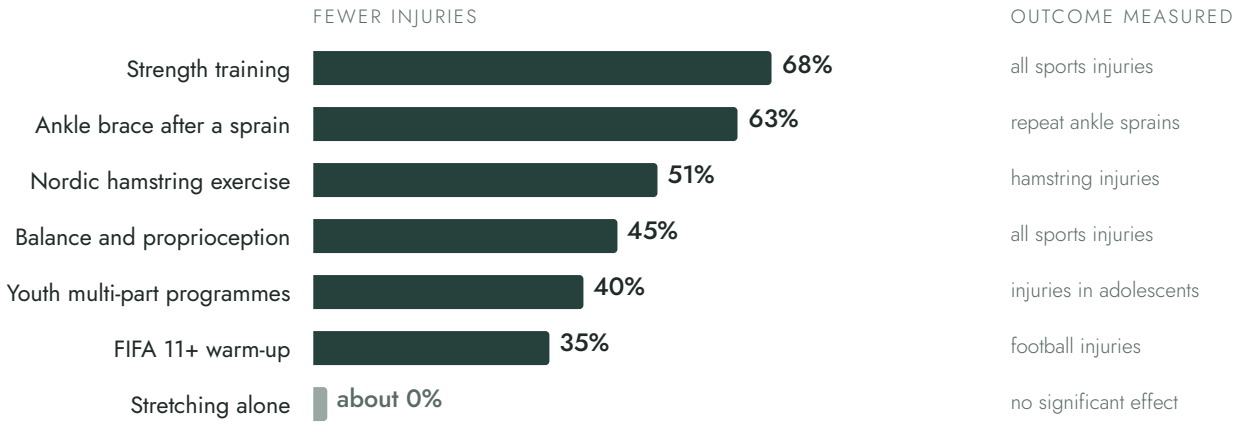
Low energy availability (REDs), poor bone health and short sleep all raise risk. Adolescents sleeping under 8 hours were 1.7 times more likely to be injured.

Biomechanical optimisation

Good landing and cutting technique is trainable and sensible, but movement screening cannot predict which individual will be injured.

Injury prevention at a glance

Relative risk reduction from meta-analyses. Each bar comes from a different analysis and injury outcome, so compare direction and rough size, not exact values.



Sources: Lauersen 2014 (strength, balance, stretching); Barelds 2018; van Dyk 2019; Soomro 2016; Al Attar 2016.

What works, and what does not

SUPPORTED BY EVIDENCE

- ✓ Strength training and structured neuromuscular warm-ups
- ✓ The Nordic hamstring exercise (roughly halves hamstring injuries)
- ✓ Balance training, and an ankle brace after a sprain
- ✓ Wrist guards in snowboarding (54% to 83% fewer wrist injuries)
- ✓ Shock-absorbing insoles in military recruits
- ✓ Rule changes, such as limiting body-checking in youth ice hockey
- ✓ Psychological interventions, such as stress management

NOT SUPPORTED

- × Stretching alone, or warm-up and cool-down stretching
- × Prophylactic knee braces
- × Instructional videos on their own
- × Modified high-top shoes for ankle sprains
- × Mouthguards for concussion (they do protect the teeth and mouth)

Load, recovery and metabolism

- **Load is more than training.** The International Olympic Committee consensus counts competition, fixture congestion, travel and psychological stress as load. Poor load management is a major risk factor.
- **High load is not harmful in itself.** Rapid increases that exceed current capacity are. Build up gradually and use athlete feedback to adjust.
- **Energy availability.** Relative Energy Deficiency in Sport (REDs) affects female and male athletes and raises injury risk, including bone stress injuries.
- **Bone health.** In female Navy recruits, daily calcium (2,000 mg) and vitamin D (800 IU) reduced stress fractures by about 20%.
- **Sleep.** Adolescents sleeping under 8 hours a night were 1.7 times more likely to be injured (observational study).

Biomechanics and screening

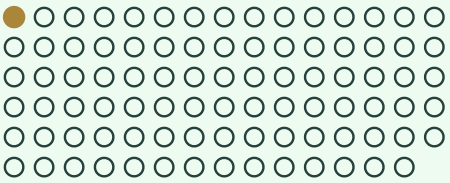
In one prospective study of 205 female athletes, knee abduction moment on landing predicted ACL injury. A later study of 710 elite female footballers and handball players found that the drop-jump test could not identify who would be injured. **Train movement quality as part of a broader programme, but do not rely on a screening test to pick out the athletes at risk.**

ACL injury prevention

ACL rupture is one of the most serious sporting knee injuries. It often happens without contact, during sudden deceleration, landing or cutting, when the trunk, hip and knee are poorly controlled. It may be accompanied by meniscal and cartilage damage and raises the long-term risk of osteoarthritis.

61%

fewer ACL injuries in female athletes doing neuromuscular warm-up programmes (high-certainty evidence; Bullock 2025).



Train about 89 athletes for a season to prevent one ACL injury (Grindstaff 2006). One dot is filled for the injury prevented.

What	Strength, jumping and landing, change of direction, with balance as part of the mix (not on its own)
How much	Minimum 10 minutes twice a week. Better: more than 20 minutes per session, several times a week
When	Start in preseason and continue through the whole season
Who	All athletes, not only those judged "high risk". Start before age 18 for the biggest effect
How	Coach-led, built into the warm-up. Use external cues such as "land softly"
Stick with it	High compliance gave about 73% fewer ACL injuries

Building a programme: four stages

Foundations 1

Strength and basic movement competence: squats, lunges, hinges, trunk control.

Single leg 2

Progress from two-legged to single-leg tasks with good knee alignment.

Landing 3

Jumps, hops and balance challenges, landing softly with hip and knee flexion.

Direction 4

Deceleration and cutting drills at increasing speed and unpredictability.

Female and young athletes

- Prevention programmes work best when started young: the effect is greatest in athletes aged 18 or under, and larger in school-age than in college or professional athletes.
- Include jumping and plyometric exercises in programmes for children and adolescents.
- Encourage sport sampling. Young athletes who specialise in one sport have about 37% more injuries than those who play several.
- Offer programmes to all young athletes. Screening, including hormonal profiling, is being researched but should not replace whole-team prevention.

Making it stick: implementation

47%

fewer injuries in the athletes who completed at least 84% of planned sessions. Lower adherence gave no clear benefit.

45% → 13%

Poor delivery can shrink a 45% ACL reduction in women's football to about 13% in the real world.

Coaches

Coach-led programmes reduce ACL injuries. Keep the programme simple, practical and part of every warm-up.

CHECKLIST FOR COACHES

- Use a structured programme (for example FIFA 11+ in football) as the warm-up, two or three times a week, all season.
- Include strength, landing, change of direction and balance. Add the Nordic hamstring exercise.
- Build training load gradually, especially after breaks, and watch for fatigue, poor sleep and under-fuelling.
- Give simple external cues: "land softly", "quiet landings", "stick the landing".
- After an ankle sprain, combine balance training with a brace for return to sport.
- Record attendance and injuries, so you know the programme is being done.

Part 1 references

1. Aaltonen S, et al. Prevention of sports injuries: systematic review of randomized controlled trials. Arch Intern Med. 2007;167(15):1585–1592.
2. Al Attar WSA, et al. How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis. Sports Med. 2016;46(2):205–217.
3. Arundale AJH, et al. Exercise-based knee and anterior cruciate ligament injury prevention: clinical practice guideline. J Orthop Sports Phys Ther. 2018;48(9):A1–A42.
4. Barelds I, et al. Ankle bracing is effective for primary and secondary prevention of acute ankle injuries in athletes. Sports Med. 2018;48(12):2775–2784.
5. Benjaminse A, et al. Novel methods of instruction in ACL injury prevention programs: a systematic review. Phys Ther Sport. 2015;16(2):176–186.
6. Bullock GS, et al. Br J Sports Med. 2025;59(22):1575–1586. doi:10.1136/bjsports-2025-109910.
7. Carder SL, et al. The concept of sport sampling versus sport specialization: preventing youth athlete injury. Am J Sports Med. 2020;48(11):2850–2857.
8. Cusimano MD, et al. Effectiveness of interventions to reduce aggression and injuries among ice hockey players: a systematic review. CMAJ. 2013;185(1):e57–e69.
9. de Vasconcelos GS, et al. Effects of proprioceptive training on the incidence of ankle sprain in athletes. Clin Rehabil. 2018;32(12):1581–1590.
10. Grindstaff TL, et al. Neuromuscular control training programs and noncontact ACL injury rates in female athletes: a numbers-needed-to-treat analysis. J Athl Train. 2006;41(4):450–456.
11. Hewett TE, et al. Biomechanical measures of neuromuscular control and valgus loading of the knee predict ACL injury risk in female athletes. Am J Sports Med. 2005;33(4):492–501.
12. John G, et al. Sports. 2025;13:39. doi:10.3390/sports13020039.
13. Krosshaug T, et al. The vertical drop jump is a poor screening test for ACL injuries in female elite soccer and handball players. Am J Sports Med. 2016;44(4):874–883.
14. Lappe J, et al. Calcium and vitamin D supplementation decreases incidence of stress fractures in female Navy recruits. J Bone Miner Res. 2008;23(5):741–749.
15. Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med. 2014;48:871–877.
16. Lauersen JB, Andersen TE, Andersen LB. Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries. Br J Sports Med. 2018;52:1557–1563.
17. Milewski MD, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. J Pediatr Orthop. 2014;34(2):129–133.
18. Mountjoy M, et al. 2023 International Olympic Committee's consensus statement on Relative Energy Deficiency in Sport (REDs). Br J Sports Med. 2023;57(17):1073–1097.
19. Myer GD, et al. The influence of age on the effectiveness of neuromuscular training to reduce ACL injury in female athletes. Am J Sports Med. 2013;41(1):203–215.
20. Pfile KR, Curioz B. Coach-led prevention programs are effective in reducing ACL injury risk in female athletes. Scand J Med Sci Sports. 2017.
21. Rössler R, et al. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. Sports Med. 2014;44(12):1733–1748.
22. Soligard T, et al. Comprehensive warm-up programme to prevent injuries in young female footballers. BMJ. 2008;337:a2469.
23. Soligard T, et al. How much is too much? (Part 1) IOC consensus statement on load in sport and risk of injury. Br J Sports Med. 2016;50:1030–1041.
24. Soomro N, et al. The efficacy of injury prevention programs in adolescent team sports: a meta-analysis. Am J Sports Med. 2016;44(9):2415–2424.
25. Steib S, et al. Dose-response relationship of neuromuscular training for injury prevention in youth athletes. Front Physiol. 2017;8:920.
26. Stephenson SD, et al. A comprehensive summary of systematic reviews on sports injury prevention strategies. Orthop J Sports Med. 2021;9(10):23259671211035776.
27. Sugimoto D, et al. Critical components of neuromuscular training to reduce ACL injury risk in female athletes: meta-regression analysis. Br J Sports Med. 2016;50(20):1259–1266.
28. van Dyk N, Behan FP, Whiteley R. Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries. Br J Sports Med. 2019;53:1362–1370.
29. Viiala J, et al. Effect of adherence to exercise-based injury prevention programmes on the risk of sports injuries. Inj Prev. 2026;32(1):31–40.

PART TWO

2 Alignment, meniscus and stability before cartilage

Why cartilage surgery fails when biomechanics are ignored. Treat the knee, not just the defect.

KEY MESSAGES

1. Cartilage restoration is not just filling a defect. Its success depends on the whole joint.
2. Three things must be right first: alignment, meniscal function and ligament stability.
3. A posterior meniscal root tear behaves like losing the whole meniscus, and varus alignment overloads both the cartilage and any root repair.
4. Osteotomy changes the load environment. It should follow careful deformity analysis and avoid overcorrection.
5. How much deformity justifies an osteotomy is still debated. Evidence supports principles, not surgical absolutes.

IN PLAIN LANGUAGE

Cartilage repair is like resurfacing a road: it will not last if the traffic keeps running over the same spot. If the leg is bow-legged (varus) or knock-kneed (valgus), if the meniscus cushion is torn or missing, or if the knee is unstable, a cartilage repair may wear out quickly. Surgeons therefore check the leg alignment, the meniscus and the ligaments first, and may correct them at the same time as, or before, repairing the cartilage.

Three pillars before cartilage

Alignment
Decides where the load goes. Define compartment loading on full-length standing X-rays.

+

Meniscus
Spreads load across the joint. Restore load-sharing where possible, especially the roots.

+

Stability
Controls translation, rotation and shear. Treat meaningful instability.

→

Then cartilage
Choose the cartilage procedure for a knee whose mechanics are already right.

Alignment redistributes load

Finding	Value	Type of evidence
Share of load through the medial compartment in a neutral knee	Up to about 70%	Gait and instrumented implant studies
Extra medial load for each degree of varus	About 5%	Approximate (five patients with instrumented implants)
Varus above which medial osteoarthritis risk clearly rises	More than 2°	Clinical cohort
Peak contact pressure: neutral vs 5° varus (medial) vs 5° valgus (lateral)	About 4 vs 7.3 vs 7.8 MPa	Six cadaver knees, unstable loading
Meniscal extrusion in valgus vs varus	1.32 vs 3.16 mm	Eight cadaver knees

Normal anatomy: the tibial joint surface sits in about 3° of varus and the femoral surface in 2° to 3° of valgus. Assess where the deformity comes from (tibia or femur), not just its size.

Meniscal root tears: a functional meniscectomy

- The posterior roots anchor the meniscus so it can resist hoop stresses. In cadavers, a medial root tear raised peak medial contact pressure by 25%, similar to removing the whole meniscus, and repair restored it.
- Removing the torn meniscus does badly: after partial meniscectomy for degenerative medial root tears, 72% of patients had a knee replacement by a mean of 14 years.
- Varus works against the repair. A computer model showed medial pressures rising from 2.43 MPa at 4° valgus to 9.09 MPa at 8° varus, and beyond 4° of varus, pressure stayed high even after root repair. A laboratory study found varus increased the force on the repair, and centralisation of the meniscus reduced it.
- In patients, preoperative varus and persisting extrusion predict long-term failure of root repair, and alignment closest to neutral gives the best results.
- When varus is corrected at the same time, results in varus knees can match those in neutral knees.

Valgus and the lateral meniscus

The lateral compartment is smaller and convex, so it tolerates overload poorly. Valgus alignment predicts lateral osteoarthritis and lateral meniscal damage, even when the valgus is mild to moderate. A varus-producing distal femoral osteotomy (DFO) can be combined with a lateral meniscal transplant: in one small series, over 80% returned to sport. The evidence for valgus is thinner than for varus.

Stability: the third pillar

Ligament deficiency changes where the femur and tibia make contact and adds shear from abnormal translation and rotation. Alignment correction cannot substitute for stability. Assess the cruciate and peripheral ligaments and treat clinically relevant instability, usually at the same time as the meniscal or cartilage procedure.

Why cartilage reconstruction fails

Alignment
Focal overload continues after an anatomically perfect repair.

Meniscus
An extruded or deficient meniscus leaves cartilage unprotected.

Stability
Instability adds abnormal motion and shear.

Subchondral bone
Poor bone support compromises fragment and graft survival.

Biology and fixation
Tissue quality and fixation strength affect healing.

Rehabilitation
Loading too much, too soon, or too little.

Failure is usually multifactorial. Look for every cause before blaming the cartilage procedure.

Osteotomy and combined surgery

A high tibial osteotomy (HTO) corrects selected varus knees and a distal femoral osteotomy (DFO) corrects selected valgus knees. Both move load away from the damaged compartment.

Planning the right osteotomy

- Measure the hip-knee-ankle angle on full-length standing radiographs.
- Find where the deformity comes from, using the medial proximal tibial angle (MPTA) and the mechanical lateral distal femoral angle (mLDFA). Correct the bone that is abnormal.
- Assess joint-line obliquity and convergence. An excessively oblique joint line shifts contact areas and meniscal loading.
- Consider tibial slope, ligament balance and patellofemoral loading.
- A common HTO target places the weight-bearing line at 50% to 55% of the tibial plateau width. With a cartilage procedure, aim for neutral to under 3° of valgus.
- **Avoid overcorrection.** In one series of HTO with osteochondral autograft, failure rose with larger corrections.

How much deformity justifies adding an osteotomy?

This is a genuine debate. Many surgeons reserve osteotomy for 5° or more of correctable deformity, partly because smaller corrections are technically demanding. Others add an osteotomy to a cartilage procedure whenever varus is present.

Study	Finding
German cartilage registry (Faber 2020)	About 3° of varus was the main trigger for surgeons to add an HTO to medial femoral cartilage repair
Propensity-matched registry (Faber 2021)	Adding HTO improved function, pain and satisfaction to 3 years, but the benefit was clear only with 5° or more of varus
ACI with or without HTO, varus under 5° (Bode 2013)	Graft survival 89.5% with HTO vs 58.3% without (not randomised)
Narrative review (Mabrouk 2024)	Recommends adding an osteotomy to a planned cartilage procedure whenever there is varus

A decision framework

Adapted from Mabrouk et al., EFORT Open Rev 2024 (Fig. 6; CC BY-NC 4.0). This is an expert proposal, not a validated decision tool. Thresholds use the MPTA and the mLDFA.

Cartilage lesion, no extra-articular deformity	Cartilage lesion plus deformity (with or without meniscal lesion)	Deformity, no cartilage lesion (with or without meniscal lesion)
MPTA over 84° and mLDFA under 90°	MPTA under 85° or mLDFA over 90°	MPTA under 81°, or mLDFA over 95°
Cartilage procedure alone	**Cartilage procedure with HTO or DFO**	**HTO (tibial), or DFO (femoral)**

Start every pathway with examination, long-leg standing radiographs and MRI.

Will cartilage regrow after an osteotomy alone?

- Often, partly. After double-level osteotomy for severe varus, second-look arthroscopy showed regeneration over 95.7% of medial femoral condyles. With "kissing" lesions, condylar regeneration was 83% vs 79% without.
- The new tissue is mostly fibrocartilage, not normal hyaline cartilage, and it matches symptoms imperfectly.
- At 11 years, HTO alone scored as well as HTO with ACI. Adding microfracture trended towards poorer scores.
- An isolated osteotomy may be enough in degenerative varus knees. Young athletes with focal defects are a different group.

Combined osteotomy and cartilage surgery

- A systematic review of 34 studies of HTO with cartilage restoration found that patient-reported outcomes generally improved, but the studies were varied and mostly observational. Younger, carefully selected patients may do better.
- A 2026 review of 40 studies (1,783 knees) found lower failure rates when an osteotomy accompanied cartilage restoration (0% to 10.5%) than with cartilage restoration alone (0% to 41.7%).
- Osteochondral autograft (OATs) with HTO had a 13% failure rate at 5 years. OATs gave better cartilage at second look than marrow stimulation.
- With osteochondral allograft, leftover malalignment increased the risk of graft failure (hazard ratio 6.55).
- Doing the osteotomy and allograft at the same operation gave less pain at 12 months than staging them.

One stage or two?

One stage restores the axis straight away and avoids a second operation. If staging is chosen, do the bony work first so that the soft-tissue or cartilage repair is not exposed to high contact pressure. Address ligament instability and osteochondral defects at the same time where possible. Patient selection must justify the extra surgery.

HTO and meniscal root repair: is the osteotomy enough?

HTO alone can improve symptoms in varus knees with a medial root tear. Adding root repair may improve healing, and the newest meta-analysis (13 studies, 725 patients) favours combined surgery for patient-reported outcomes. However, complete root healing occurred in only a third on average, and combined repair did not consistently reduce extrusion or arthritis progression. Do not automatically add every procedure.

CHECKLIST BEFORE CARTILAGE SURGERY

- Full-length standing radiographs: hip-knee-ankle angle, MPTA, mLDFA, joint-line obliquity.
- MRI: meniscal roots, extrusion, ramp lesions, subchondral bone, opposing cartilage.
- Examination for ACL, PCL, collateral and posterolateral corner laxity.
- Decide what to correct and whether in one stage or two. If staged, bone first.
- Discuss realistic outcomes, the chance of reoperation and the rehabilitation commitment.

Part 2 references

1. Ade-Conde AM, et al. Combined high tibial osteotomy and root repair improves patient-reported outcomes in medial meniscus posterior root tears. J ISAKOS. 2026;16:101035.
2. Allaire R, et al. Biomechanical consequences of a tear of the posterior root of the medial meniscus: similar to total meniscectomy. J Bone Joint Surg Am. 2008;90(9):1922–1931.
3. Berk AN, et al. The effect of lower limb alignment on tibiofemoral joint contact biomechanics after medial meniscus posterior root repair: a finite-element analysis. J Am Acad Orthop Surg. 2024;32(11):e558–e567.
4. Bode G, et al. A non-randomized controlled clinical trial on ACI in cartilage defects of the medial femoral condyle with or without HTO in patients with varus deformity of less than 5°. Arch Orthop Trauma Surg. 2013;133:43–49.
5. Chung KS, et al. Preoperative varus alignment and postoperative meniscus extrusion are the main long-term predictive factors of clinical failure of meniscal root repair. Knee Surg Sports Traumatol Arthrosc. 2021;29(12):4122–4130.
6. Daniel AV, et al. The role of alignment in treating meniscus pathology. Curr Rev Musculoskelet Med. 2025;18:149–159.
7. Deichsel A, et al. Arthroscopic centralization of the medial meniscus reduces load on a posterior root repair under dynamic varus loading. Am J Sports Med. 2024.
8. Dugdale TW, Noyes FR, Styer D. Preoperative planning for high tibial osteotomy. Clin Orthop Relat Res. 1992;(274):248–264.
9. Dzidzishvili L, et al. Combined HTO and medial meniscus posterior root repair: a systematic review. Arthroscopy. 2026.
10. Faber S, et al. Decision making for concomitant HTO in cartilage repair patients. Arch Orthop Trauma Surg. 2020;140:1437–1444.
11. Faber S, et al. Cartilage repair with or without additional HTO: a propensity score-matched study. Cartilage. 2021;13(1 Suppl):1206S–1216S.
12. Felson DT, et al. Valgus malalignment is a risk factor for lateral knee osteoarthritis incidence and progression. Arthritis Rheum. 2013;65(2):355–362.
13. Ferruzzi A, et al. Cartilage repair procedures associated with HTO in varus knees: clinical results at 11 years. Knee. 2014;21:445–450.
14. Ghasemi SA, et al. High tibial osteotomy combined with cartilage restoration: a systematic review. J Clin Orthop Trauma. 2024;50:102360.
15. Grassi A, et al. Am J Sports Med. 2024;52(7):1813–1819.
16. Halder A, et al. J Bone Joint Surg Am. 2012;94(11):1023–1029.
17. Inaba HI, Arai MA, Watanabe WW. Influence of the varus-valgus instability on the contact of the femoro-tibial joint. Proc Inst Mech Eng H. 1990;204(1):61–64.
18. Kim KI, et al. Mid- to long-term outcomes after medial open-wedge HTO in patients with radiological kissing lesion. Orthop J Sports Med. 2022;10:23259671221101875.
19. Kim MK, Ko BS, Park JH. The proper correction of the mechanical axis in HTO with concomitant cartilage procedures. J Orthop Surg Res. 2019;14:281.
20. Kumagai K, et al. Mosaic osteochondral autograft transplantation versus bone marrow stimulation with opening-wedge HTO. Arthroscopy. 2018;34:233–240.
21. Lamba A, et al. Long-term outcomes of partial meniscectomy for degenerative medial meniscus posterior root tears. Orthop J Sports Med. 2024;12(9):23259671241266593.
22. León SA, et al. Long-term results of fresh osteochondral allografts and realignment osteotomy for cartilage repair in the knee. Bone Joint J. 2019;101-B:46–52.
23. Mabrouk A, et al. Combined knee osteotomy and cartilage procedure for varus knees: friend or foe? EFORT Open Rev. 2024;9:173–180.
24. Meyer LE, et al. Concomitant procedures for knee cartilage injuries: an international Delphi consensus statement. J Cartil Jt Preserv. 2024;4(3):100198.
25. Meyer LE, et al. Concomitant procedures around cartilage restoration surgery: a systematic review. Arthroscopy. 2026;42(11):2802–2814.
26. Minzlaff P, et al. Osteochondral autologous transfer combined with valgus HTO: long-term results and survivorship. Am J Sports Med. 2013;41:2325–2332.
27. Nakayama H, et al. Cartilage repair examined by second-look arthroscopy following double-level osteotomy. Knee. 2021;29:411–417.
28. Puzzitiello RN, et al. Return to sport and outcomes after concomitant lateral meniscal allograft transplant and distal femoral varus osteotomy. Arthroscopy. 2020;36(1):253–260.
29. Ridley TJ, et al. Minimum 2-year clinical outcomes of medial meniscus root tears in relation to coronal alignment. Am J Sports Med. 2022;50(5):1254–1260.
30. Schipplein OD, Andriacchi TP. J Orthop Res. 1991;9(1):113–119.
31. Vosoughi F, et al. HTO and concurrent medial meniscus root repair vs HTO alone: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2025;33:3361–3374.
32. Wang D, et al. Knee joint line obliquity causes tibiofemoral subluxation that alters contact areas and meniscal loading. Am J Sports Med. 2021;49(9):2351–2360.
33. Willinger L, et al. Varus alignment increases medial meniscus extrusion and peak contact pressure. Knee Surg Sports Traumatol Arthrosc. 2020;28(4):1092–1098.
34. Zitsch BP, et al. Patient-reported outcomes for large bipolar osteochondral allograft transplantation with realignment osteotomies. J Knee Surg. 2021;34:1260–1266.

PART THREE

3 Meniscus repair: 5 pearls

Save the meniscus, and keep the patient's trust. From the SKICON 2026 "Pearls of Wisdom" session, Pune.

THE FIVE PEARLS

1. **Select your patient well:** the right tear in the right knee.
2. **Plan your surgery:** read the MRI, look for hidden lesions and plan co-procedures.
3. **Right procedure, right time, right patient, right result.**
4. **Monitor the rehabilitation:** progress by milestones, not just dates.
5. **Counsel and carefully manage the unhappy repair.**

IN PLAIN LANGUAGE

The meniscus is a shock absorber that spreads load across the knee. Removing it raises the long-term risk of arthritis, so surgeons now repair many tears that would once have been removed. Most repairs heal, but about 1 in 5 fail over 5 or more years. Choosing the right tear, a stable and well-aligned knee, and sticking to the rehabilitation all improve the chance of success.

Why we repair

- The meniscus shares load by converting it into circumferential (hoop) stress. Partial meniscectomy gives worse long-term clinical and radiological results than preservation.
- Many tears once called "irreparable" should now be repaired, including root, ramp and radial tears.
- Modern repairs fail in 19.5% at a minimum of 5 years. Medial repairs fail more often than lateral (23.9% vs 12.6%).

1 Select your patient well

THE TEAR

- A traumatic tear, not a degenerative lesion
- In the vascular zone: red-red or red-white
- Vertical longitudinal tears heal best
- Root, ramp and radial tears: repair, do not resect
- Confirm tissue quality at arthroscopy

THE PATIENT

- A stable knee, or stabilise it at the same sitting
- Check alignment in medial tears
- Medial repairs fail more often (hazard ratio 3.7 in 918 repairs)
- Age alone is not a contraindication
- Will they commit to the rehabilitation?

2 Plan your surgery

- Review the MRI for tear pattern, length, zone and extrusion.
- Look for hidden lesions: ramp lesions, root tears and lateral meniscus oblique radial tears (LMORT).
- Obtain long-leg films for root tears and varus knees (see Part 2).

- Choose the technique and equipment in advance, and plan co-procedures such as ACL reconstruction, osteotomy or cartilage surgery.
- Consent for repair, and for meniscectomy as a fallback if the tissue cannot be saved.

3 Right procedure, right time

Tear type	Typical repair technique
Vertical longitudinal	All-inside or inside-out sutures
Radial	Tie-grip or side-to-side sutures
Posterior root	Transtibial pull-out, with or without centralisation
Ramp lesion	Posteromedial portal or all-inside

- **Right patient:** a stable, well-aligned knee. Repair as early as possible.
- **Prepare the bed:** rasp and trephine to stimulate healing.
- **Fixation:** anatomic and stable, but not over-tensioned.
- **Biology helps:** repairs done with ACL reconstruction failed half as often (hazard ratio 0.5). In one large cohort, repairs with ACL reconstruction failed in 14% at 6 years, and medial repairs failed earlier than lateral (2.1 vs 3.7 years).
- **Safety:** protect the saphenous nerve medially and the peroneal nerve laterally.

4 Monitoring rehabilitation is key

There is no consensus on the best protocol, and accelerated rehabilitation has not been linked to more failures. Rehabilitation depends on the tear type.

Simple vertical tears

Early motion and weight-bearing as tolerated.

Root, radial and complex tears

Protected weight-bearing and limited flexion in the early weeks. Avoid loaded deep flexion early on.

TYPICAL MILESTONES

Protect
Protect the repair as the tear type requires; restore extension and quadriceps control

Full range
Full range of motion

Full weight
Full weight-bearing

Running
When pain-free with no effusion; then strength and hop tests

Return to sport
Pivoting sport: typically 6 months after isolated repair, 9 months with ACL reconstruction

Return-to-sport timings are typical, not fixed. Progress by milestones: check effusion, pain and range of motion at every visit, and keep the surgeon and physiotherapist talking.

5 The unhappy meniscus repair

ASSESS

- Expect it: modern repairs fail in about 1 in 5 at 5 or more years.
- Causes: re-tear or failure to heal, ACL graft failure, malalignment, implant irritation or saphenous neuritis, chondral pain or stiffness.
- MRI signal can persist after a repair has healed. Consider an MR arthrogram.

COUNSEL AND MANAGE

- Discuss the risk of failure and reoperation before surgery.
- Listen, acknowledge the problem and set realistic timelines.
- Treat the cause: revise the repair, stabilise the knee, realign.
- Partial meniscectomy if irreparable. Consider transplant in selected young patients.
- A failed repair carries about 5 times the odds of osteoarthritis and poorer function.

Part 3 references

1. Bhatia S, et al. Meniscal root tears: significance, diagnosis, and treatment. Am J Sports Med. 2014;42(12):3016–3030.
2. Kopf S, et al. Management of traumatic meniscus tears: the 2019 ESSKA meniscus consensus. Knee Surg Sports Traumatol Arthrosc. 2020;28(4):1177–1194.
3. Nepple JJ, et al. Meniscal repair outcomes at greater than 5 years: a systematic review and meta-analysis. J Bone Joint Surg Am. 2022. doi:10.2106/JBJS.21.01303.
4. Rönnblad E, et al. Predictive factors for failure of meniscal repair: a retrospective dual-center analysis of 918 consecutive cases. Orthop J Sports Med. 2020;8(3).
5. Rönnblad E, et al. Failed meniscal repair increases the risk for osteoarthritis and poor knee function at an average of 9 years follow-up. Knee Surg Sports Traumatol Arthrosc. 2022. doi:10.1007/s00167-021-06442-w.
6. Spang RC, et al. Rehabilitation following meniscal repair: a systematic review. BMJ Open Sport Exerc Med. 2018;4(1):e000212.
7. Westermann RW, et al. Meniscal repair with concurrent ACL reconstruction: operative success and patient outcomes at 6-year follow-up. Am J Sports Med. 2014;42(9):2184–2192.

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