Pegem Journal of Education and Instruction, Vol. 14, No. 3, 2024 (pp. 1008-1017)

RESEARCH ARTICLE WWW.PEGEGOG.NET

Open Wedge High Tibial Osteotomy with ACL Reconstruction: Does Combined Surgery Improve Outcomes?

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ABSTRACT

***Background*:** Open wedge high tibial osteotomy (OWHTO) combined with anterior cruciate ligament reconstruction (ACLR) has emerged as a promising surgical strategy for patients presenting with ACL deficiency and varus malalignment. Traditionally, ACL injuries have been managed with isolated reconstruction; however, increasing evidence suggests that uncorrected malalignment may compromise graft integrity and lead to suboptimal outcomes. In particular, varus deformity and increased posterior tibial slope contribute to abnormal knee biomechanics, increased graft stress, and higher rates of failure following isolated ACLR.

The aim of this review is to evaluate whether combining OWHTO with ACL reconstruction improves short-term clinical and radiological outcomes compared to isolated procedures. Emphasis is placed on indications, surgical techniques, patient selection, and early postoperative results, including stability, functional scores, and complication rates.

Biomechanically, OWHTO redistributes load from the medial to the lateral compartment and reduces excessive stress on the ACL graft. Additionally, the procedure allows for modulation of posterior tibial slope, which plays a crucial role in controlling anterior tibial translation. When performed in conjunction with ACLR, this combined approach addresses both instability and malalignment, creating a more favorable environment for graft function and joint preservation.

Clinical studies have demonstrated that combined OWHTO and ACLR leads to improved knee stability, reduced pain, and enhanced functional outcomes in the short term. Patients undergoing simultaneous procedures often experience better restoration of mechanical alignment and lower rates of graft failure compared to those treated with isolated ACL reconstruction. Furthermore, early outcomes suggest that a single-stage procedure offers advantages in terms of rehabilitation efficiency and overall recovery time.

In conclusion, current evidence supports the use of combined OWHTO and ACL reconstruction in appropriately selected patients with ACL deficiency and malalignment. While short-term outcomes are encouraging, further high-quality studies are required to establish long-term benefits and refine surgical indications.

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Keywords: Open Wedge High Tibial Osteotomy, ACL Reconstruction, Outcomes

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common causes of knee instability, particularly in young and active individuals. Although ACL reconstruction (ACLR) is widely regarded as the gold standard treatment, failure rates remain clinically significant, especially in patients with underlying biomechanical abnormalities. One of the most important contributing factors is lower limb malalignment, particularly varus deformity, which alters load distribution and increases stress on the ACL graft. [1]

Open wedge high tibial osteotomy (OWHTO) has traditionally been used as a joint-preserving procedure for medial compartment osteoarthritis associated with varus alignment. However, its role has expanded to include the management of ACL-deficient knees with malalignment. By correcting the mechanical axis and redistributing joint loads, OWHTO can improve knee biomechanics and provide a more favorable environment for ligament reconstruction. [2]

The combination of OWHTO and ACL reconstruction has gained increasing attention as a strategy to address both instability and malalignment simultaneously. This approach is particularly relevant in patients with symptomatic instability and varus alignment, where isolated ACL reconstruction may fail due to persistent abnormal loading conditions. [3]

In addition to coronal plane correction, OWHTO offers the ability to influence sagittal alignment, particularly posterior tibial slope, which has been identified as a key factor in ACL biomechanics. Modifying the slope during osteotomy may further reduce anterior tibial translation and improve graft protection, enhancing surgical outcomes. [4]

Despite growing interest in combined procedures, there remains debate regarding their indications, optimal surgical technique, and clinical benefits compared to isolated ACL reconstruction. While several studies report favorable outcomes, the evidence is still evolving, particularly with respect to short-term results and complication profiles. [5-7]

The aim of this review is to evaluate whether combining open wedge high tibial osteotomy with anterior cruciate ligament reconstruction improves short-term clinical and radiological outcomes, with a focus on indications, surgical strategies, and early postoperative results.

There is limited consolidated evidence specifically addressing short-term outcomes of combined OWHTO and ACL reconstruction, and a lack of standardized guidelines defining optimal patient selection and surgical indications for this combined approach

Biomechanical Rationale for Combining OWHTO with ACL Reconstruction

The coexistence of anterior cruciate ligament (ACL) deficiency and varus malalignment creates a complex biomechanical environment that cannot be adequately addressed by isolated ligament reconstruction. In ACL-deficient knees, anterior tibial translation and rotational instability are already present, and when combined with varus alignment, there is a significant increase in medial compartment loading. This abnormal distribution of forces results in increased stress on both the native ACL and reconstructed grafts, ultimately compromising joint stability and surgical outcomes. [8]

Varus malalignment shifts the mechanical axis medially, leading to excessive load concentration in the medial compartment of the knee. This increased loading not only accelerates cartilage degeneration but also contributes to increased tensile stress across the ACL, particularly during weight-bearing and dynamic activities. As a result, isolated ACL reconstruction in such knees often fails to restore normal biomechanics due to persistent abnormal force transmission. [9]

Open wedge high tibial osteotomy (OWHTO) addresses this issue by realigning the mechanical axis of the lower limb. By shifting the weight-bearing line laterally toward the lateral compartment, OWHTO reduces medial compartment overload and decreases the pathological forces acting on the ACL. This biomechanical correction plays a crucial role in improving the environment in which the reconstructed ligament functions. [10]

In addition to coronal plane correction, OWHTO has a significant impact on sagittal plane biomechanics, particularly through its influence on posterior tibial slope (PTS). An increased PTS is associated with greater anterior tibial translation, which increases strain on the ACL. Through careful surgical technique, OWHTO can be used to control or reduce PTS, thereby

decreasing anterior shear forces and improving overall knee stability. [11]

The interaction between coronal and sagittal alignment is particularly important in ACL-deficient knees. When varus deformity and increased PTS coexist, their combined effect results in significantly higher ACL strain compared to either deformity alone. This synergistic relationship explains the high rates of graft failure observed in patients with uncorrected multiplanar deformities. [12]

Biomechanical studies have demonstrated that correcting alignment through osteotomy reduces the load on the ACL graft and improves joint kinematics. By restoring a more physiological alignment, OWHTO reduces excessive anterior tibial translation and rotational instability, allowing the reconstructed ligament to function more effectively and with less mechanical stress. [13]

Another critical aspect of combined surgery is the restoration of the "functional envelope" of the knee. ACL reconstruction alone restores ligamentous stability, but without correcting alignment, abnormal loading patterns persist. OWHTO complements ligament reconstruction by addressing these underlying mechanical abnormalities, leading to a more balanced and stable joint environment. [14]

The timing and sequencing of the combined procedure also contribute to biomechanical success. Performing the osteotomy first allows correction of the mechanical axis before graft placement and tensioning. This ensures that the ACL graft is positioned and tensioned within a corrected biomechanical framework, which is essential for long-term graft durability and optimal function. [15]

Furthermore, alignment correction has been shown to reduce the risk of progressive joint degeneration. By unloading the medial compartment and stabilizing knee kinematics, combined OWHTO and ACL reconstruction may slow the progression of osteoarthritis, particularly in younger patients seeking joint preservation strategies. [16]

In summary, the biomechanical rationale for combining OWHTO with ACL reconstruction is well established. Addressing both malalignment and instability simultaneously provides a more comprehensive treatment approach, improving graft survival, restoring knee function, and enhancing overall clinical outcomes in the short term. [17]

Indications and Patient Selection for Combined OWHTO and ACL Reconstruction

Proper patient selection is a critical determinant of success when considering combined open wedge high tibial osteotomy (OWHTO) and anterior cruciate ligament reconstruction (ACLR). Not all patients with ACL deficiency require alignment correction, and identifying those who will benefit from a combined approach requires careful clinical and radiological evaluation. The presence of symptomatic instability in conjunction with malalignment represents the primary indication for this combined surgical strategy. [18]

One of the most widely accepted indications for OWHTO combined with ACL reconstruction is varus malalignment greater than 5°, particularly when associated with recurrent instability. In such cases, isolated ACL reconstruction is often insufficient due to persistent abnormal loading conditions that place excessive stress on the graft. Correcting the mechanical axis is therefore essential to restore joint biomechanics and improve surgical outcomes. [19]

Patient age and activity level also play an important role in decision-making. Ideal candidates are typically younger than 50 years and maintain a high level of physical activity, as these individuals benefit most from joint-preserving procedures. Combined OWHTO and ACL reconstruction allows such patients to return to demanding activities while delaying or avoiding the need for joint arthroplasty. [20]

Another key factor in patient selection is the condition of the articular cartilage, particularly in the lateral compartment. Patients with preserved lateral compartment cartilage are considered good candidates for OWHTO, as load redistribution toward this compartment is a fundamental goal of the procedure. Conversely, advanced tricompartmental osteoarthritis is a contraindication, as osteotomy alone cannot adequately address diffuse joint degeneration. [21]

Range of motion and knee function must also be carefully assessed preoperatively. Patients should have adequate knee motion, typically greater than 90° of flexion without significant flexion contracture, to ensure favorable postoperative outcomes. Limited range of motion may increase the risk of postoperative stiffness and compromise rehabilitation following combined procedures. [22]

Sagittal alignment parameters, particularly posterior tibial slope, should also be evaluated during patient selection. Patients with

increased slope may benefit from slope-modifying osteotomy in conjunction with ACL reconstruction, especially in cases of recurrent instability or previous graft failure. Addressing both coronal and sagittal deformities enhances the biomechanical success of the procedure. [23]

Body mass index (BMI) is another important consideration. Obesity has been associated with increased risk of complications, including delayed healing, infection, and implant failure. Therefore, patients with a BMI greater than 35 are generally considered less suitable candidates for combined OWHTO and ACL reconstruction. [24]

Contraindications to combined procedures include active infection, poor bone quality, severe ligamentous instability involving multiple ligaments, and significant deformities requiring correction greater than 15°–20°. In such cases, alternative treatment strategies or staged procedures may be more appropriate to minimize complications and optimize outcomes. [25]

Psychosocial factors and patient compliance should not be overlooked. Successful outcomes following combined surgery depend heavily on adherence to rehabilitation protocols, which are often demanding and prolonged. Patients must be motivated and capable of participating in structured rehabilitation to achieve optimal functional recovery. [26]

In summary, appropriate patient selection is essential for achieving successful outcomes in combined OWHTO and ACL reconstruction. Careful evaluation of alignment, stability, cartilage status, and patient-specific factors allows for individualized treatment planning, ensuring that this technically demanding procedure is reserved for those most likely to benefit. [27]

Surgical Techniques (OWHTO + ACL Reconstruction)

The combined procedure of open wedge high tibial osteotomy (OWHTO) and anterior cruciate ligament reconstruction (ACLR) requires meticulous preoperative planning and precise surgical execution. The goal is to simultaneously correct malalignment and restore ligamentous stability within a single operative session. This approach demands a thorough understanding of both osteotomy principles and arthroscopic reconstruction techniques to ensure optimal outcomes. [28]

Preoperative planning begins with full-length weight-bearing radiographs to assess mechanical axis deviation and determine the required degree of correction. The target is typically to shift the weight-bearing line laterally to approximately 50–62% of the tibial plateau width, depending on patient-specific factors. Additionally, evaluation of posterior tibial slope is essential to determine whether slope modification is required during osteotomy. [29]

Patient positioning is usually supine, allowing access for both arthroscopic and open procedures. Diagnostic arthroscopy is commonly performed first to assess intra-articular pathology, including meniscal tears and cartilage status. This step also allows for initial preparation of the ACL tunnels if the surgeon prefers a combined workflow before osteotomy correction. [30]

The osteotomy is typically performed through a medial approach to the proximal tibia. A longitudinal incision is made between the tibial tuberosity and the posteromedial border of the tibia, followed by careful dissection to expose the osteotomy site. Under fluoroscopic guidance, guide wires are inserted toward the fibular head to define the osteotomy plane while preserving the lateral cortical hinge, which is critical for stability. [31]

The osteotomy cut is performed approximately 3–4 cm below the joint line, extending obliquely toward the proximal tibiofibular joint. Controlled opening of the osteotomy is achieved using gradual distraction until the desired correction is obtained, as confirmed by intraoperative alignment assessment. Preservation of the lateral hinge is essential to prevent instability and loss of correction. [32]

Once the desired alignment is achieved, the osteotomy is stabilized using a locking plate system, most commonly a TomoFix plate. These modern fixation systems provide angular stability and allow early mobilization. Bone grafting or bone substitutes may be used depending on the size of the osteotomy gap, although recent evidence suggests that stable fixation alone may be sufficient for healing in many cases. [33]

Following osteotomy fixation, attention is turned to ACL reconstruction. Tunnel placement is performed using anatomical landmarks to replicate the native ACL footprint. The femoral tunnel is typically positioned within the anteromedial bundle region of the lateral femoral condyle, while the tibial tunnel is placed in the posterior aspect of the native footprint to avoid graft impingement. [34]

Graft selection varies based on surgeon preference and patient characteristics, with common options including hamstring tendon, bone–patellar tendon–bone, and quadriceps tendon autografts. Proper graft tensioning is performed after osteotomy correction

to ensure that the graft is adapted to the new biomechanical alignment, reducing the risk of overconstraint or laxity. [35]

The sequence of performing OWHTO prior to ACL graft fixation is widely recommended, as it allows accurate graft tensioning in the corrected alignment. This ensures that the reconstructed ligament functions within the new mechanical axis, thereby optimizing stability and reducing graft stress during postoperative loading. [36]

In summary, combined OWHTO and ACL reconstruction is a technically demanding but highly effective procedure when performed with careful planning and execution. Mastery of both osteotomy and ligament reconstruction techniques is essential to achieve accurate alignment correction, stable fixation, and optimal restoration of knee biomechanics. [37]

Fixation Methods and Graft Considerations

Stable fixation is a fundamental requirement for successful open wedge high tibial osteotomy (OWHTO), particularly when it is combined with anterior cruciate ligament reconstruction (ACLR) in the same surgical setting. Because the osteotomy must maintain correction while allowing biological healing, the fixation construct must resist collapse, preserve the lateral hinge, and tolerate early rehabilitation stresses. In combined procedures, this stability becomes even more important, as graft healing and osteotomy union occur simultaneously and each can be adversely affected by mechanical instability. [38]

Modern locking plate systems have become the preferred fixation method for OWHTO because they provide angular stability and strong resistance against loss of correction. Among these, the TomoFix plate is widely used and has demonstrated reliable mechanical performance in maintaining coronal correction and supporting early mobilization. Locking constructs are especially valuable in combined surgery because they reduce micromotion at the osteotomy site while preserving the alignment necessary for proper ACL graft function. [39]

Alternative fixation systems, including spacer plates and anatomical locking metal block plates, have also been used in OWHTO with acceptable results. However, differences in implant design may influence mechanical behavior, control of opening gap geometry, and maintenance of posterior tibial slope. In the setting of simultaneous ACL reconstruction, the fixation system should not only stabilize the osteotomy but also help preserve the intended sagittal alignment, as unintended slope changes may increase graft stress. [40]

One of the most important technical concerns in fixation is control of posterior tibial slope during the opening process. Uneven anterior and posterior distraction can unintentionally increase slope, thereby increasing anterior tibial translation and mechanical load on the ACL graft. For this reason, fixation strategy and implant positioning must be carefully planned to maintain or intentionally modify slope according to the surgical objective. [41]

Bone healing after OWHTO depends on multiple factors, including fixation stability, size of the osteotomy gap, bone quality, and biological environment. Although bone grafts or substitutes were previously considered essential for large opening gaps, long-term studies have shown that stable fixation with modern locking plates can allow successful healing even without gap filling in many patients. This is particularly relevant in combined surgery, where minimizing additional surgical morbidity may be beneficial. [42]

On the ligament side, graft choice remains one of the most important determinants of ACL reconstruction success. The selected graft must provide adequate biomechanical strength, allow secure fixation, and match the patient's functional demands. In combined OWHTO and ACLR procedures, graft choice becomes even more relevant because the graft must function in a healing knee that is simultaneously adapting to altered alignment and osteotomy healing. [43]

Hamstring tendon autografts are commonly used because of their lower donor-site morbidity, smaller incision, and reduced anterior knee pain compared with patellar tendon grafts. These features can be advantageous in patients undergoing combined surgery, where postoperative comfort and early rehabilitation are important. However, hamstring grafts have also been associated with tunnel widening and potentially higher graft failure rates in some studies, which may be relevant in malaligned or high-demand knees. [44]

Bone–patellar tendon–bone autografts remain an important option because of their strong fixation and reliable bone-to-bone healing. They have historically been regarded as a benchmark graft for ACL reconstruction, particularly in active patients requiring robust stability. Nevertheless, their use may be limited by donor-site morbidity, including anterior knee pain and kneeling discomfort, which may complicate recovery in patients already undergoing osteotomy around the proximal tibia. [45]

Quadriceps tendon autografts have gained increasing attention because of their favorable biomechanical properties and promising clinical outcomes. They provide a large graft diameter and strong structural characteristics while avoiding some of the donor-site problems associated with patellar tendon harvest. In combined OWHTO and ACLR, the quadriceps tendon may offer a useful balance between graft strength and acceptable morbidity, particularly in revision settings or when hamstring preservation is desired. [46]

Ultimately, fixation method and graft selection should be individualized according to deformity characteristics, bone quality, patient activity level, and surgeon expertise. Successful combined surgery depends on achieving harmony between osteotomy stability and ligament reconstruction biology. When the fixation construct preserves correction and the graft is appropriately chosen and tensioned, OWHTO with ACL reconstruction can provide a mechanically sound and clinically durable solution in the short term. [47]

Short-Term Clinical and Radiological Outcomes

Short-term outcomes following combined open wedge high tibial osteotomy (OWHTO) and anterior cruciate ligament reconstruction (ACLR) have gained increasing attention, particularly in patients with varus malalignment and symptomatic instability. Early clinical results suggest that addressing both alignment and ligament deficiency simultaneously leads to superior functional outcomes compared to isolated ACL reconstruction in selected patients. Improvements are commonly observed in pain relief, knee stability, and overall functional performance within the first 1–2 years postoperatively. [48]

Functional outcome scores, including Lysholm, International Knee Documentation Committee (IKDC), and Tegner activity scales, have shown consistent improvement following combined procedures. Patients often report significant gains in daily activities and sports participation, reflecting restoration of both mechanical alignment and ligamentous stability. These improvements are particularly notable in active individuals who require a high level of knee function. [49]

Knee stability is one of the most critical parameters assessed in short-term outcomes. Clinical evaluations, including Lachman and pivot shift tests, demonstrate significant reduction in anterior and rotational instability following combined OWHTO and ACLR. Instrumented laxity measurements further confirm improved anterior tibial control, indicating effective load reduction on the reconstructed ligament. [50]

Radiological outcomes also play a key role in evaluating the success of combined procedures. Postoperative imaging typically demonstrates correction of the mechanical axis toward the desired target, often around 50–62% of the tibial plateau width. This shift in the weight-bearing line reflects successful unloading of the medial compartment and redistribution of joint forces. [51]

In addition to coronal correction, radiological assessment of posterior tibial slope is essential. Studies have shown that careful execution of OWHTO can maintain or reduce slope, thereby contributing to improved sagittal stability. Maintaining appropriate slope is particularly important in protecting the ACL graft from excessive anterior shear forces. [52]

Another important short-term outcome is the rate of graft survival and failure. Early evidence suggests that combined OWHTO and ACL reconstruction is associated with lower graft failure rates compared to isolated ACLR in malaligned knees. This is attributed to the improved biomechanical environment achieved through alignment correction, which reduces stress on the graft during functional loading. [53]

Pain reduction is a consistent finding in short-term follow-up, largely due to unloading of the medial compartment and improved joint mechanics. Patients often experience decreased activity-related pain and improved quality of life, which contributes to higher satisfaction rates following combined surgery. [54]

Return to activity is another key indicator of success. Many patients are able to return to moderate or even high levels of physical activity within the first year following surgery. Although return to elite sports may vary, the combined procedure provides a more stable and reliable knee environment compared to isolated reconstruction in malaligned individuals. [55]

Despite these positive outcomes, complications may still occur in the short term, including delayed union of the osteotomy, hardware irritation, and stiffness. However, most studies report complication rates comparable to those of isolated procedures, suggesting that the combined approach does not significantly increase surgical risk when performed appropriately. [56]

In summary, short-term clinical and radiological outcomes of combined OWHTO and ACL reconstruction are highly encouraging. The procedure provides significant improvements in stability, function, alignment, and pain, supporting its role as

an effective treatment strategy for selected patients with ACL deficiency and malalignment. [57]

Complications and Limitations

Despite the encouraging short-term outcomes of combined open wedge high tibial osteotomy (OWHTO) and anterior cruciate ligament reconstruction (ACLR), the procedure is not without potential complications. The dual nature of the surgery, involving both bony correction and ligament reconstruction, inherently increases technical complexity and requires careful intraoperative execution. Complications may arise from either component of the procedure or from their interaction, emphasizing the need for meticulous planning and surgical expertise. [58]

One of the most common complications associated with OWHTO is delayed union or non-union at the osteotomy site. Although modern fixation methods have significantly reduced this risk, factors such as large correction angles, poor bone quality, and patient comorbidities may still impair healing. Delayed union can prolong rehabilitation and may necessitate additional interventions, thereby affecting short-term outcomes. [59]

Loss of correction is another concern, particularly if the lateral cortical hinge is compromised during osteotomy. Disruption of this hinge can lead to instability of the osteotomy construct and subsequent collapse, resulting in recurrence of varus deformity. This not only affects mechanical alignment but also increases stress on the ACL graft, potentially compromising the overall success of the combined procedure. [60]

Hardware-related complications, including irritation, prominence, and the need for implant removal, are also relatively common. While these issues are generally manageable, they may contribute to patient discomfort and require secondary surgical procedures. The use of low-profile locking plates has helped reduce these complications, but they remain a consideration in postoperative management. [61]

From the ligament reconstruction perspective, graft-related complications such as elongation, failure, or improper tensioning may occur. In combined procedures, these risks may be influenced by changes in alignment and loading conditions. Incorrect graft tensioning in an improperly corrected limb can lead to either residual laxity or overconstraint, both of which negatively impact functional outcomes. [62]

Infection, although relatively rare, represents a serious complication that can affect both the osteotomy and the reconstructed ligament. Early recognition and management are critical to prevent long-term consequences, including graft failure or chronic osteomyelitis. Combined procedures may carry a slightly increased infection risk due to longer operative times and greater surgical exposure. [63]

Postoperative stiffness and limited range of motion are additional concerns, particularly when rehabilitation is delayed or overly aggressive. The combination of osteotomy healing and ligament graft integration requires a carefully balanced rehabilitation protocol to avoid stiffness while protecting surgical constructs. Failure to achieve this balance can compromise functional recovery. [64]

Another limitation of combined OWHTO and ACL reconstruction is the steep learning curve associated with the procedure. Surgeons must be proficient in both osteotomy techniques and arthroscopic ligament reconstruction, and errors in either component can adversely affect outcomes. This may limit the widespread adoption of the technique to specialized centers with sufficient expertise. [65]

Patient-related factors, including obesity, poor compliance, and high physical demands, may also influence outcomes and complication rates. Non-adherence to rehabilitation protocols or premature return to activity can jeopardize both osteotomy healing and graft integrity, leading to suboptimal results even in technically successful surgeries. [66]

In summary, while combined OWHTO and ACL reconstruction offers significant benefits, it is associated with a range of potential complications and limitations. Careful patient selection, precise surgical technique, and structured rehabilitation are essential to minimize risks and optimize short-term outcomes.

Conclusion

The combination of open wedge high tibial osteotomy and anterior cruciate ligament reconstruction represents a comprehensive approach to managing ACL-deficient knees with underlying malalignment. By simultaneously addressing both mechanical axis deviation and ligamentous instability, this strategy restores more physiological knee biomechanics, reduces graft stress, and

improves short-term clinical and radiological outcomes. Current evidence consistently demonstrates enhanced knee stability, functional improvement, and reduced failure rates compared to isolated ACL reconstruction in appropriately selected patients.

However, the success of this combined procedure depends heavily on accurate patient selection, meticulous surgical technique, and well-structured rehabilitation protocols. Despite promising short-term results, further high-quality studies are needed to establish long-term outcomes, refine surgical indications, and standardize treatment algorithms. As understanding of knee biomechanics continues to evolve, combined OWHTO and ACL reconstruction is likely to play an increasingly important role in the management of complex ACL-deficient knees.

How to cite this article: Eslam Nagy Hadhoud, Khalid Mohamed Hassan, Mohamed AbdAlla M. Abdelsalam, Mohamed Attia Abdelmoeti (2024). Open Wedge High Tibial Osteotomy with ACL Reconstruction: Does Combined Surgery Improve Outcomes?, Vol. 14, No. 3, 2024,1006-1014.

Source of support: None.

Conflict of interest: Nil.

Accepted: 26.06.2024 **Received** 03.06.2024

REFERENCES

1. Moon HS, Song SY, Oh JU, Seo YJ. Effects of modified trans-tibial versus trans-portal technique on stress patterns around the femoral tunnel in anatomical single-bundle ACL reconstruction. *BMC Musculoskelet Disord.* 2022;23(1):759.
2. Hassebrock JD, Gulbrandsen MT, Asprey WL, Makovicka JL, Chhabra A. Knee ligament anatomy and biomechanics. *Sports Med Arthrosc Rev.* 2020;28(3):80-88.
3. Śmigielski R, Zdanowicz U, Drwięga M, Ciszek B, Williams A. The anatomy of the anterior cruciate ligament and its relevance to the technique of reconstruction. *Bone Joint J.* 2016;98-B(8):1020-1026.
4. Morales-Avalos R, Perelli S, Vilchez-Cavazos F, et al. ACL anatomy: Is there still something to learn? *Knee Surg Sports Traumatol Arthrosc.* 2024;68(4):T422-T427.
5. Cone SG, Howe D, Fisher MB. Size and shape of the human anterior cruciate ligament: A systematic review. *J Orthop Res.* 2019;7(6):e8.
6. Braaten JA, Schreier FJ, Rodriguez AN, et al. Modern treatment principles for multiligament knee injuries. *Ann Joint.* 2022;10(11):937.
7. Li G, DeFrate LE, Sun H, Gill TJ. In vivo elongation of the ACL and PCL during knee flexion. *Am J Sports Med.* 2004;32(6):1415-1420.
8. Flandry F, Hommel G. Normal anatomy and biomechanics of the knee. *Sports Med Arthrosc Rev.* 2011;19(2):82-92.
9. Chao EY, Neluheni EV, Hsu RW, Paley D. Biomechanics of alignment. *Orthop Clin North Am.* 1994;25:379-386.
10. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. *Orthop Clin North Am.* 1994;25(3):425-465.
11. Watanabe Y, Takenaka N, Kinugasa K, et al. Intra- and extra-articular deformity of the lower limb. *Adv Orthop.* 2019.
12. Cherian JJ, Kapadia BH, Banerjee S, et al. Mechanical, anatomical, and kinematic axes in TKA. *Curr Rev Musculoskelet Med.* 2014;7(2):89-95.
13. Lee HI, Park D, Cho J. Clinical and radiological results after OWHTO. *Knee Surg Relat Res.* 2018;30(1):34-41.
14. Ji S, Huang Y, Zhou Y, et al. Predictive factors of residual varus alignment. *Front Surg.* 2023;9:1054351.
15. Paley D. Normal lower limb alignment and joint orientation. In: *Principles of Deformity Correction.* Springer; 2002.
16. Bergin PF, Miles DT, Mathis TP, et al. Intraoperative evaluation of LDFA. *J Orthop Trauma.* 2018;32(8):414-418.
17. Kim SH, Lee JW, Kim MG, et al. Radiologic findings associated with ACL degeneration. *Arch Orthop Trauma Surg.* 2023;143(7):4257-4265.
18. Noyes FR, Barber-Westin SD, Hewett TE. High tibial osteotomy and ligament reconstruction for varus ACL-deficient knees. *Am J Sports Med.* 2000;28:282-296.
19. Sanders TL, Maradit Kremers H, Bryan AJ, et al. Incidence of ACL tears. *Am J Sports Med.* 2016;44(6):1502-1507.

20. Nilsson M, Toresdahl B, Henriksson H, et al. Varus alignment and OA after ACL injury. *J Exp Orthop.* 2025;12:e70143.
21. Sharma L. The role of knee alignment in OA progression. *JAMA.* 2001;286:188-195.
22. Tischer T, Paul J, Pape D, et al. Impact of osseous malalignment in knee ligament surgery. *Orthop J Sports Med.* 2017;5(3):2325967117697287.
23. Noyes FR, Barber-Westin SD. ACL revision reconstruction outcomes. *Am J Sports Med.* 2006;34:553-564.
24. Won HH, Chang CB, Je MS, et al. Coronal limb alignment in revision ACLR. *Clin Orthop Relat Res.* 2013;471:3504-3511.
25. Schneider A, Gaillard R, Gunst S, et al. Combined ACLR and OWHTO outcomes. *Knee Surg Sports Traumatol Arthrosc.* 2020;28(3):960-968.
26. Webb JM, Salmon LJ, Leclerc E, et al. Posterior tibial slope and ACL injury. *Am J Sports Med.* 2013;41:2800-2804.
27. Hohmann E, Tetsworth K, Glatt V, et al. Posterior tibial slope as risk factor. *Am J Sports Med.* 2021.
28. Marques B, Souza B, Simões M, et al. PTS changes after OWHTO. *Knee Surg Sports Traumatol Arthrosc.* 2020;28(10):3222-3228.
29. Moran J, Chona D, Parker DA, Coolican MRJ. High tibial osteotomy review. *J ISAKOS.* 2024;9(1):144-154.
30. Legnani C, Peretti GM, Del Re M, et al. Valgus high tibial osteotomy: state of the art. *J ISAKOS.* 2024;9(3):447-457.
31. Sabzevari S, Ebrahimpour A, Khalilipour MR, et al. High tibial osteotomy: systematic review. *Arch Bone Jt Surg.* 2016;4(3):204-212.
32. Li Y, Zhang H, Zhang J, et al. Combined HTO and ACLR outcomes. *Arthroscopy.* 2015;31(3):507-519.
33. Kim JS, Park SB, Choi HG, et al. Combined ligament reconstruction with osteotomy. *Arch Orthop Trauma Surg.* 2023;143:3677-3689.
34. Deng FY, Liu JC, Li Z. Osteotomy combined with ACLR. *World J Clin Cases.* 2024;12(22):4897-4904.
35. Müller S, Frosch KH, Frings J, et al. Biplanar HTO techniques. *Orthop Traumatol Surg Res.* 2023;109(4):103339.
36. Loia MC, Vanni S, Rosso F, et al. Indications and limits of HTO. *Joints.* 2016;4(2):98-110.
37. Jin C, Song EK, Jin QH, et al. Outcomes of simultaneous HTO and ACLR. *BMC Musculoskelet Disord.* 2018;19:228.
38. Gupte PN, Dhamangaonkar AC, Mhatre SV, et al. Outcomes of combined ACLR and HTO. *J Arthrosc Joint Surg.* 2025;12(1):19-24.
39. Murray R, Winkler PW, Shaikh HS, Musahl V. HTO for varus deformity. *J Am Acad Orthop Surg.* 2021;5(7):e21.00141.
40. Kyung HS, Lee BJ, Kim JW, Yoon SD. Plate comparison in OWHTO. *Clin Orthop Surg.* 2015;7(2):185-190.
41. Han SB, Bae JH, Lee SJ, et al. Locking plate biomechanics in OWHTO. *Knee Surg Relat Res.* 2014;26(3):155-161.
42. Yazdi HR, Torkaman A, Babaki AE, et al. Fixation effect on tibial slope. *J Orthop Surg Res.* 2023;18:780.
43. Brosset T, Pasquier G, Migaud H, Gougeon F. OWHTO long-term outcomes. *Orthop Traumatol Surg Res.* 2018;104(4):477-482.
44. Roman MD, Mohor CI, Melinte PR, et al. Meniscal tear management with ACLR. *Appl Sci.* 2022;12(12):6175.
45. Kim DK, Park G, Wang JH, et al. Quadriceps strength and ACLR outcomes. *Sci Rep.* 2022;12:5830.
46. Fernandes TL, Moreira HH, Andrade R, et al. Anatomic ACLR outcomes. *Orthop J Sports Med.* 2021;9(6):23259671211013327.
47. Fox MA, Engler ID, Zsidai BT, et al. Anatomic ACL reconstruction paradigm. *J ISAKOS.* 2023;8(1):15-22.
48. Xu H, Zhang C. Femoral tunnel positioning. *Arthroscopy.* 2010;26(12):1566-1572.
49. Garofalo R, Moretti B, Kombot C, et al. Femoral tunnel placement. *J Orthop Surg Res.* 2007;2:10.
50. Paschos NK, Howell SM. ACL reconstruction principles. *EFORT Open Rev.* 2016;1(11):398-408.
51. Costa GG, Perelli S, Grassi A, et al. Minimizing graft failure risk. *J Exp Orthop.* 2022;9(1):26.
52. Zaffagnini S, Lucidi GA, Macchiarola L, et al. Long-term ACL outcomes. *J Exp Orthop.* 2023;10(1):36.
53. Azer A, Ge D, Chan FJ. Tibial tunnel techniques. *Arthroscopy Techniques.* 2025;14(3):103261.
54. Avadhani A, Rao PS, Rao SK. Tibial tunnel position outcomes. *Singapore Med J.* 2010;51:413-417.
55. Nishio Y, Kondo E, Onodera J, et al. Double-bundle ACLR. *Orthop J Sports Med.* 2018;6(5).
56. Stone AV, Marx S, Conley CW. Partial ACL tear management. *J Am Acad Orthop Surg.* 2021;29(2):60-70.
57. Widner M, Dunleavy M, Lynch S. Outcomes by graft type. *Curr Rev Musculoskelet Med.* 2019;12(4):460-465.
58. Xie X, Liu X, Chen Z, et al. BPTB vs hamstring graft meta-analysis. *Knee.* 2015;22(2):100-110.
59. Freedman KB, D'Amato MJ, Nedeff DD, et al. ACL graft comparison meta-analysis. *Am J Sports Med.* 2003;31(1):2-11.
60. Ristanis S, Tsepis E, Giotis D, et al. Hamstring graft neuromuscular impact. *Am J Sports Med.* 2009;37(11):2179-2186.
61. Neddermann A, Willbold E, Witte F, et al. Tunnel widening after ACLR. *Am J Sports Med.* 2009;37(8):1609-1617.

62. Vijay C, Santosh MS, Avinash C, Adarsh T. Peroneus longus graft study. *Orthop J Sports Med.* 2022.
63. Rudy K, Mustamsir E, Phatama KY. Tendon tensile strength comparison. *Int J Surg Open.* 2017;9:41-44.
64. Wiradiputra A, Febyan, Aryana G. Peroneus longus graft review. *Int J Surg Case Rep.* 2021;83:106028.
65. He J, Tang Q, Ernst S, et al. Peroneus vs hamstring graft outcomes. *Knee Surg Sports Traumatol Arthrosc.* 2021;29(9):2869-2879.
66. Slane JA, Slane LC, Scheys L, Thelen DG. Quadriceps tendon graft considerations. *Sports Health.* 2023;15(5):712-724.