Clinical Outcomes of High Tibial Osteotomy for Knee Instability

A Systematic Review

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Background: In recent years there has been an increasing interest in high tibial osteotomy (HTO) to treat patients with chronic knee instability due to posterolateral corner (PLC), posterior cruciate ligament (PCL), and anterior cruciate ligament (ACL) insufficiencies with concurrent malalignment in the coronal and/or sagittal plane.

Purpose: To perform a systematic review of the use of HTO for the treatment of knee ligament instability with concurrent malalignment.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review of the literature was conducted for the treatment of combined knee ligament instability and malalignment with HTO using the Cochrane Central Register of Controlled Trials, PubMed, and MEDLINE (1980 to present); the queries were performed in July 2015. Terms searched included the following: high or proximal tibial osteotomy, unstable, instability, laxity, subluxation, tibial slope, and malalignment, in the knee joint. Inclusion criteria were as follows: HTO to treat instability of the knee joint in the sagittal and/or coronal plane, minimum 2-year follow-up with reported outcomes measures, English language, and human studies. Animal, basic science, and cadaveric studies were excluded as well as editorials, reviews, expert opinions, surveys, special topics, letters to the editor, and correspondence.

Results: The search resulted in 460 studies. After applying exclusion criteria and removing duplicates, 13 studies were considered. Of the studies reviewed, knee ligament pathologies, previous surgeries, and measurement of knee stability were heterogeneous. However, all studies reported an improvement in knee stability after HTO. Most studies reported improvement in outcome scores. However, other studies did not provide preoperative scores for comparison. Reported complication rates ranged from 0% to 47%.

Conclusion: Although HTO has been highly advocated and used in treating patients with ligamentous knee instability, there remains a paucity of high-quality studies. Included studies report improvement of instability as well as relatively high patient satisfaction and rate of return to sports. The heterogeneity of the pathology treated, follow-up time, and outcome measures limit comparison between studies.

Keywords: high tibial osteotomy; proximal tibial osteotomy; instability; laxity; malalignment; tibial slope

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One or more of the authors has declared the following potential conflict of interest or source of funding: R.F.L. receives royalties from Arthrex and Smith & Nephew; is a paid consultant for Arthrex, Ossur, and Smith & Nephew; receives research royalties from Arthrex, Livinatc, Ossur, and Smith & Nephew; and has patents pending with Ossur and Smith & Nephew.

The Orthopaedic Journal of Sports Medicine, 4(3), 2325967116633419 DOI: 10.1177/2325967116633419 © The Author(s) 2016

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(2) to protect the graft(s) from abnormally high stress in a 
malaligned knee,12 and (3) to restore stability.18 Nevertheless, 
additional surgery could expose the patient to an 
added risk from the procedure itself or from prolonged 
rehabilitation.12

An important consideration in performing an HTO for 
treatment of malalignment and ligament instabilities is the 
ability to simultaneously correct both the coronal and 
sagittal axis malalignment with 1 cut (biplanar osteotomy). 
Failure of the surgeon to recognize this ability can lead to 
 inadvertent negative consequences for the graft (ie, 
increasing posterior slope with a valgus-producing HTO for 
an ACL-deficient patient can increase stresses on the 
ACL graft).14

Literature available regarding HTO and knee instability 
is highly heterogeneous with respect to indications, timing, 
and outcomes. The purpose of this study was to 

determine whether HTO improves postoperative stability, 
according to patient-reported stability, as well as: the 
Lachman test and the pivot shift test in cases of ACL deficiency, 
the posterior drawer test for PCL deficiency, and the reverse pivot shift 
test and the varus stress test in cases of PLC deficiency. 
Secondarily, we sought to determine postoperative patient 
reported outcomes, return to activity, patient satisfaction, 
and complication rates.

METHODS

Article Identification and Selection

This study was conducted in accordance with the 2009 
Preferred Reporting Items for Systematic Review and 
Meta-Analysis (PRISMA) statement.17 A systematic 
review of the literature about the existing evidence for the 
treatment of ligamentous instability of the knee with HTO 
was performed using the Cochrane Central Register of 
Controlled Trials, PubMed, and MEDLINE from 1980 to 
present; the queries were performed in July 2015.

The literature search strategy included the following: 
search 1: (“HTO” OR “High tibial osteotomy” OR “PTO” 
OR “Proximal Tibial Osteotomy”) AND (unstable OR 
instability OR laxity OR subluxation OR “tibial slope” OR 
“knee malalignment” OR “knee alignment” OR “chronic 
posterolateral” OR “revision knee surgery”); search 2: 
“tibia” AND “osteotomy” AND (unstable OR instability 
OR laxity OR subluxation). Inclusion criteria consisted of 
high or proximal tibial osteotomy to treat instability of the 
knee joint, minimum 2-year follow-up with report on 
outcomes, English language, and human studies. Exclusion 
criteria included animal studies, basic science studies, 
cadaveric studies, editorials, reviews, expert opinions, 
surveys, special topics, letters to the editor, and correspondence. Additionally, we excluded all other joint studies 
besides the knee joint.

Three investigators (C.S.D., D.J.L., J.C.) independently 
reviewed the abstracts from all identified articles. Full-text 
articles were obtained for review if necessary to allow the 
application of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed 
and reconciled to verify that no relevant articles were missing 
from the systematic review. Inclusion and exclusion 
criteria were sequentially used to identify relevant articles, 
as shown in the PRISMA flowchart (Figure 1). For studies 
not available online, print copies were accessed from the 
library at the Steadman Philippon Research Institute, Vail, 
Colorado, USA.

Data Collection

Following the classification from Wright et al,27 the level of 
evidence was assigned. The information was collected from 
the abstracts of the included studies. Pre- and postopera-
tive instability was extracted and recorded as subjective 
instability, Lachman test, and pivot shift test. Additionally, 
patient demographics, follow-up, patient satisfaction, 
subjective outcomes, return to sport, and complications were 
extracted and recorded. For continuous variables (eg, age, 
timing, follow-up, outcome scores), the mean and range 
were collected if reported. Data were recorded into a custom 
Microsoft Excel spreadsheet (Microsoft Corp) using a mod-
ified information extraction table.9
Bias

There can be inherent selection and performance bias in evidence level 3 and level 4 studies because of the lack of randomization and prospective comparative control groups, especially in populations characterized by heterogeneity in injuries. Selected studies were reviewed to ensure that authors minimized bias while recognizing the constraints present with such studies.

RESULTS

The systematic search performed using the previously mentioned keywords identified 361 studies after duplicates were removed. Of these, 183 were not related to our topic, leaving 178 studies. Of these, 66 studies did not include or report on instability, and 27 of the remaining studies did not report on outcomes. Other studies that were eliminated included 25 cadaveric/biomechanical studies, 18 reviews, 13 case reports, 10 expert opinions, 4 surgical technique reports, 1 that did not include HTOs, and 1 instructional course lecture. After applying all exclusion criteria, 13 studies were considered for insightful data, including 3 studies with all opening-wedge cases and 6 studies with all closing-wedge cases. Four studies included a mixture of opening- and closing-wedge osteotomies (Tables 1-4). The included studies reported on a total of 353 patients treated with HTO for several different etiologies of knee instability. The mean follow-up was reported between 2.5 and 12 years.

There was substantial heterogeneity of indications, subjective outcomes, and objective outcomes within the included studies. The most commonly reported measures were subjective instability, patient satisfaction, return to sport, and complications. On the contrary, the use of subjective outcomes scores varied widely.

HTO in ACL-Deficient Knees

Eleven of the studies evaluated the effect of HTO in patients with ACL deficiency. Seven of the studies had HTO with ACL reconstruction either concurrently or as a staged procedure, while 1 study performed HTO as the treatment procedure. In 3 studies, the subjects had either HTO alone or HTO with ACL reconstruction. Two of the 11 studies reported on knee stability using the pivot shift and Lachman tests; 2 studies reported on patient subjective feeling of instability, pivot shift, and Lachman tests; 1 study used only the Lachman test; and 3 studies did not report on knee stability (Table 1). HTO alone was reported to improve knee stability in ACL-deficient knees. However, combined HTO with ACL reconstruction either as a staged procedure or simultaneous procedure was reported to improve postoperative stability better than HTO alone, as judged by patient-reported stability, the Lachman test, and the pivot shift test. HTO alone did not always restore adequate stability. Nonetheless, Noyes et al reported no significant difference between patients treated with HTO alone and those treated with HTO and ACL reconstruction. However, it should be noted that in this study patients were advised to only return to light recreational athletic activities.

The knee outcome subjective scores were also used in some studies, but the outcome scores used were heterogeneous. Three studies reported on Tegner activity score with a preoperative mean of 3.5 in 2 studies and a postoperative mean of 5.0 in 3 studies. Neuschwander et al did not report preoperative Tegner score. The Lysholm score was reported in only 2 studies. The Lysholm score improved from 48.6 preoperatively to 81.7 postoperatively. Six studies reported the International Knee Documentation Committee (IKDC) scores. The mean preoperative IKDC score was 48.5 based on 2 studies. In 4 studies, the mean postoperative IKDC score was 73.6. In the other 2 studies, the knees were evaluated as normal or nearly normal (IKDC “A” and “B”) in 60.5%, abnormal (IKDC “C”) in 32.5%, and severely abnormal in 7% of patients.

High Tibial Osteotomy in PLC-Deficient and Combined PLC-Deficient Knees

Four studies included patients with combined PLC-deficient knees. There were few patients with combined ligament pathologies in the studies included in this review. Furthermore, combined ligament injuries were highly heterogeneous. Patients with combined ligament pathology were treated first with HTO, and those with persistent instability were treated with a staged ligament reconstruction. Arthur et al reported on 21 patients with combined chronic PLC deficiency and genu varum malalignment. In their study, 38% of the patients obtained satisfactory stability after HTO and did not require ligament reconstruction. Naudie et al reported on 17 knees in 16 patients that received either medial opening-wedge HTO or combined medial opening-wedge HTO with tibial tubercle osteotomy for hyperextension-varus thrust. Among them, 5 of 16 patients reported continued posterolateral instability and went on to have second-stage PCL reconstruction after initial HTO. In a study by Noyes et al, all patients (N = 18) with triple varus (tibiofemoral varus geometry, separation of lateral compartment, increased external tibial rotation and hyperextension with varus recurvatum) included in the study required PLC reconstruction, while those with double varus (tibiofemoral varus geometry, separation of lateral compartment due to deficiency of the lateral soft tissue) did not need this procedure after HTO. None of the studies reported pre- and postoperative grading of instability tests for patients with PCL and or PLC deficiencies.

Patient Satisfaction, Complications, and Return to Sport

Patient satisfaction at final follow-up was reported in 7 studies and ranged from 75% to 97%, with improvement in subjective stability and all outcomes scores regardless of preoperative diagnosis and procedure performed. Of patients who were dissatisfied in this systematic review, 1 had significant weight gain postoperatively and others...
| Authors                  | Follow-up, y | No. of Patients | Procedure                                                                 | Subjective Instability | Lachman                      | Pivot Shift |
|-------------------------|--------------|-----------------|---------------------------------------------------------------------------|-------------------------|------------------------------|-------------|
| Trojani et al<sup>25</sup> | 6            | 34              | Medial opening-wedge HTO + ACLR                                          | Preop: 100%             |                              |             |
| Zaffagnini et al<sup>28</sup> | 6.5          | 32              | Lateral closing-wedge HTO + ACLR                                         | Preop: 100%             |                              |             |
| Arthur et al<sup>1</sup>  | 3.1          | 21              | Medial opening-wedge osteotomy; only 6/21 were isolated varus and PLCR deficient, the rest were combined ligament pathology; 13/21 had a second-stage ligament reconstruction | Preop: 100%             |                              |             |
| Bonin et al<sup>4</sup>   | 12           | 29              | Lateral closing-wedge osteotomy + ACLR: 25                               | Preop: 10.6             |                              |             |
| Naudie et al<sup>18</sup> | 4.7          | 16 (17 HTOs)    | Medial opening-wedge HTO: 14                                             | Preop: 100%             |                              |             |
| Williams et al<sup>26</sup> | 3.8          | 26              | Lateral closing-wedge HTO: 12                                            | Grade 1: 4, 15          | Grade 0: 0, 12                |             |
| Badhe and Forster<sup>4</sup> | 2.8          | 14              | 5/14 lateral closing-wedge osteotomy + ACLR                              | Preop: 14/14 (100%)     |                              |             |
| Noyes et al<sup>21</sup>  | 4.5          | 41              | 41/41 lateral closing-wedge HTO                                          | Elimination of giving way |                              |             |
| Lattermann and Jakob<sup>15</sup> | 5.8          | 30              | 10 medial opening-wedge osteotomy                                       | Postop: 19/27 (70%)     |                              |             |
| Boss et al<sup>5</sup>     | 6.25         | 54              | Lateral closing-wedge + ACLR: 24                                         | Postop: 2/3 had no giving way symptoms | Postop: Negative in 93% of patients |             |
| Neuschwander et al<sup>19</sup> | 2.5          | 5               | Lateral closing-wedge osteotomy + ACLR                                   | Preop: 100%             | Postop: 2/5 (20%) had 1+     |             |

(continued)
expressed dissatisfaction from not being able to return to a desired level of activity. Rates of return to sport were reported in 11 of 13 studies and ranged from 18% to 80%. However, the definition of return to sport varied between studies as did counseling on postoperative limitations, making comparison difficult. For example, in the study by O’Neill and James, only 30% of patients returned to running or jumping activities while 70% of patients were satisfied performing activities of daily living. The study by Neuschwander et al discouraged patients from returning to athletic activity, and the study by Noyes et al recommended only returning to light recreational athletic activities.

Complications were reported in 12 of 13 studies, ranged from 0% to 47%, and included a wide variety of pathologies. The most commonly reported complication was postoperative stiffness due to arthrofibrosis that resulted in loss of range of motion. Postoperative stiffness accounted for a total of 11 patients in 4 of the 13 studies. All of these patients underwent manipulation under anesthesia with or without arthroscopic lysis of adhesions. Hardware irritation requiring surgical removal was reported in 4 studies and was experienced by 9 patients. Delayed tibial union was a reported complication in 2 patients (1 was treated with an external fixator and 1 was treated with prolonged protected weightbearing) and nonunion in 1 patient (treated with an external fixator), all of whom went on to complete union and outcome scores that were not significantly different than their cohorts. Of note, Bonin et al reported postoperative deep vein thrombosis confirmed by ultrasound in 23% of their patient population. Across all studies, only 1 case of deep vein thrombosis was reported. The summarized results of HTO regarding instability are listed in Table 1, patient satisfaction and outcomes in Table 2, complications in Table 3, and return to sport in Table 4.

**DISCUSSION**

The most important finding of this systematic review was that HTO has an important role in treating patients with knee ligament instability, with good reported outcomes for ACL, PCL, and combined PLC injuries in the knee. Knee ligament injuries are heterogeneous, and therefore, a thorough preoperative diagnostic workup is important, including clinical examination and imaging studies (particularly long leg alignment radiographs and stress radiographs for PCL and collateral ligament injuries).

High tibial osteotomy can either be performed alone, with simultaneous ligament reconstruction, or as a staged procedure with HTO first followed by ligament reconstruction in cases of persistent instability. There are conflicting results of whether to perform ACL reconstruction simultaneously with HTO. In a study by Noyes et al, the authors reported no significant differences between patients treated with HTO alone, HTO with a Losee-type extra-articular procedure, or HTO with ACL reconstruction regarding symptoms of pain, swelling, and giving way. Lattermann and Jakob reported high complication rates with simultaneous HTO and ACL reconstruction procedures compared with either HTO alone or a staged procedure. No other study in this review reported a high complication rate with simultaneous HTO and ACL reconstruction procedures. The other studies included in this review suggest that HTO can be safely performed simultaneously with ACL reconstruction. A recent systematic review by Li et al reported improvement of subjective scores, and most participants returned to recreational sports after a simultaneous HTO and ACL reconstruction in young patients with medial compartment osteoarthritis and ACL deficiency.

A staged procedure, however, seems to be advantageous in knees with PLC and PCL injuries. Several studies performed high tibial osteotomy first followed by ligament reconstruction performed at a later stage for patients who had persistent instability. The rationale for performing HTO first is to correct malalignment and protect any future reconstruction grafts from excessive stress and to restore stability. Several studies reported improvement of stability in patients with posterolateral and/or lateral ligament deficiency to the degree that they did not require secondary ligament reconstruction procedures. However, a staged procedure has the disadvantage of longer rehabilitation. Therefore, different etiologies of knee instability may require different approaches.
## TABLE 2
### Satisfaction and Outcomes

| Authors and Procedure | Satisfaction | IKDC | Tegner Activity | Lysholm | Cincinnati | HSS | VAS | WOMAC |
|-----------------------|--------------|------|-----------------|---------|------------|-----|-----|--------|
| Trojani et al<sup>25</sup> 34 medial opening-wedge HTO + ACLR | 97% satisfied | Postop: 77 | | | | | | |
| Zaffagnini et al<sup>28</sup> 32 lateral closing-wedge HTO + ACLR | Preop: 58 | Preop: 3 | | | | | | |
| | Postop: 72 | Postop: 5 | | | | | | |
| Arthur et al<sup>1</sup> 21 medial opening-wedge HTO | Preop: | Postop: | | | | 43.3 | 3.8 (reconstruction), 61.5 | |
| Bonin et al<sup>4</sup> 25 lateral closing-wedge osteotomy; 5 medial opening-wedge osteotomy | Preop: | Postop: | | | | | | |
| Naudie et al<sup>28</sup> 14 medial opening-wedge HTO; 3 medial opening-wedge HTO + tibial tubercle osteotomy (5/16 patients reported continued posterolateral instability and went on to have 2nd-stage PCLR after initial HTO) | 15/16 (93.8%) satisfied | Preop: 3.25 | | | | | | |
| Williams et al<sup>26</sup> 12 lateral closing-wedge HTO; 14 lateral closing-wedge HTO + ACLR | 76% very satisfied, 3.8 (HTO), 4.9 (HTO), 4.7 (HTO + ACLR) | Preop: 3.6 (HTO + ACLR) | 46.8 (HTO), 76.3 (HTO), 80.8 (HTO + ACLR) | | | | | |
| | reasonably satisfied; n = 2 | Postop: 4.7 (HTO + ACLR) | 76.3 (HTO), 80.8 (HTO + ACLR) | | | | | |
| | dissatisfied | Postop: | | | | | | |
| Badhe and Forster<sup>2</sup> 5 lateral closing-wedge osteotomy + ACLR; 2 lateral closing-wedge osteotomy + PCLR; 1 lateral closing-wedge osteotomy + ACLR + PCLR; 1 medial opening-wedge osteotomy + ACLR + PCLR; 1 medial opening-wedge osteotomy + PCLR + PCLR; 1 lateral closing-wedge osteotomy + ACLR + PCLR; 2 medial opening-wedge osteotomy alone; 1 lateral closing-wedge osteotomy alone | Preop: 53 (range, 40-58) | Postop: 74 (range, 58-82) | 8 good | 4 fair | | | | |
| Noyes et al<sup>13</sup> 41 lateral closing-wedge osteotomy + ACLR | Preop: 63 | Postop: 82 | | | | | | |
| Lattermann and Jakob<sup>15</sup> 10 medial opening-wedge osteotomy; 17 lateral closing-wedge osteotomy; 11 HTO alone; 8 HTO + ACLR (2 stage); 8 HTO + ACLR | 93% satisfied; n = 2 | Preop: 23/27 (85%) | improved | 1 unchanged | | | | |
| | 1 deteriorated | | | | | | | |
| Boos et al<sup>5</sup> 24 lateral closing-wedge osteotomy + ACLR; 3 medial opening-wedge + ACLR | 75% satisfied | | | | | | | |

(continued)
Addressing both the coronal and sagittal planes is essential to restore knee stability. Biplanar HTO simultaneously addresses alignment in the coronal plane and tibial slope in the sagittal plane. Recently, Dejour et al. reported on the outcomes of second-revision ACL reconstruction combined with tibial deflexion osteotomy (when it exceeds 12°) at minimum follow-up of 2 years suggesting that tibia slope correction protects a reconstructed ACL graft from stress failure. Likewise, Sonnery-Cottet et al. performed a proximal tibial anterior closing-wedge osteotomy in a re-

### TABLE 2 (continued)

| Authors and Procedure | Satisfaction | IKDC | Tegner Activity | Lysholm | Cincinnati | HSS | VAS | WOMAC |
|-----------------------|--------------|------|-----------------|---------|------------|-----|-----|-------|
| Neuschwander et al.19 | 5 lateral closing-wedge osteotomy + ACLR | Postop: 52 | Level 4: n = 2 | Postop: 88 | Level 6: n = 2 | 2 excellent, 2 | Level 7: n = 2 | good, 1 fair |
| Noyes et al.20        | 16 lateral closing osteotomy + ACLR | 88% satisfied, | 78% felt knee | improved | | | | |
| O'Neill and James22   | 10 lateral closing-wedge osteotomy + ACLR | Preop: 39 | | | | | | |

ACLR, anterior cruciate ligament reconstruction; HSS, Hospital for Special Surgery; HTO, high tibial osteotomy; IKDC, International Knee Documentation Committee; PCLR, posterior cruciate ligament reconstruction; PLCR, posterolateral corner reconstruction; postop, postoperative; preop, preoperative; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

### TABLE 3

Return to Sport

| Authors                  | Return to Sport                                                                 |
|--------------------------|-------------------------------------------------------------------------------|
| Trojani et al.125        | 80% returned to desired level of participation                                |
| Zaffagnini et al.128     | 18% able to perform preinjury level of activity                               |
| Arthur et al.13          | —                                                                             |
| Bonin et al.14           | 14/29 (48%) played regular intense sports postoperatively                     |
|                          | 11/29 (38%) played moderate sports postoperatively                           |
| Naudie et al.16          | 2 sedentary patients able to return to work                                   |
|                          | 1 patient with isolated PLC able to return to semiprofessional hockey with only a medial opening-wedge HTO |
| Other cases were not reported |                                                               |
| Williams et al.126       | 4 (16%) participating in competitive sports                                   |
|                          | 19 (76%) participating in recreational sports                                 |
|                          | 2 (8%) unable to perform light athletic activities                           |
| Badhe and Forster2       | 93% participated in recreational activities but no patients returned to competitive sports |
| Noyes et al.21           | 9/41 (22%) able to run without limitation preoperatively                       |
|                          | 16/41 (39%) at last follow-up able to run without limitation                  |
|                          | 14/41 (34%) able to participate in sports preoperatively                      |
|                          | 27/41 (66%) at last follow-up able to participate in sports                  |
| Patients were encouraged only to return to light recreational athletic activity | |
| Lattermann and Jakob15   | —                                                                             |
| Boss et al.17            | 89% practiced in their preoperative job                                       |
|                          | 52% participated at a high level of sport activity compared with preoperation |
|                          | 27% regained pretraumatic sports activity                                     |
|                          | 15% sports activity was reduced compared with preoperation                   |
| Neuschwander et al.19    | Patients encouraged not to be athletically active postoperatively             |
|                          | 4/5 returned to recreational sports, 1 limited to jogging                    |
| Noyes et al.20           | 22/41 (54%) participating in sports activities preoperatively                |
|                          | 24/41 (59%) at last follow-up returned to sports with no symptoms            |
| O'Neill and James22      | 3/10 (30%) returned to running or jumping postoperatively                     |
|                          | Remaining 7/10 (70%) satisfied performing activities of daily living         |

*HTO, high tibial osteotomy; PLC, posterolateral corner.*
showed that increasing the tibial slope. This reported better results with opening-wedge HTO than closing-wedge HTO in patients with triple varus deformity. Closing-wedge HTO has been reported to decrease the tibial slope.\textsuperscript{6,19,21} Closing-wedge HTO has therefore been advocated for chronic ACL-deficient knees where decreasing the tibial slope is desired. Both opening- and closing-wedge HTO have been reported to decrease the patellar height.\textsuperscript{11,13} The possibility of a shortened patellar tendon should be evaluated when considering a bone–patella tendon–bone autograft for a later ACL reconstruction.

Favorable outcomes of combined HTO and ligamentous procedures are evident in this systematic review. Studies with combined ACL reconstruction and HTO tended to report higher postoperative activity levels when compared with HTO alone. However, postoperative Tegner activity scores improved in all patient groups, even those who had received HTO alone. This may be more reflective of the impact knee instability has on activities of daily living. Noyes et al\textsuperscript{20} reported good results and no significant difference between HTO alone compared with both HTO with ACL reconstruction and HTO with extra-articular Losee procedure. For this reason, HTO is an interesting option in patient populations where ligament reconstruction does not always have favorable outcomes, such as older patient populations and patients with low general activity demands.

As an alternative to HTO, distal femoral osteotomy may be useful for the treatment of malaligned knees with medial knee ligamentous instability. Hetsroni et al\textsuperscript{10} recently performed a biomechanical analysis of lateral opening-wedge distal femoral osteotomy in valgus malaligned cadaveric knees that were superficial medial collateral ligament–deficient. They reported a decrease in medial joint opening at 30° of knee flexion when under a valgus load of 9.8 N. Clinical studies that focus on the results of a distal femoral osteotomy in patients with combined genu

| Authors                  | Complications                                                                 |
|--------------------------|-------------------------------------------------------------------------------|
| Trojani et al\textsuperscript{25} | Not reported                                                                 |
| Zaffagnini et al\textsuperscript{26} | 4 patients (12%); 2 arthrofibrosis and lysis of adhesions, 1 hardware irritation and deep hardware removal, 1 delayed tibial union |
| Arthur et al\textsuperscript{1}  | 5 patients (24%); 4 hardware irritation and deep hardware removal, 1 infection after 2nd-stage ACL/PCL reconstruction |
| Bondie et al\textsuperscript{4}  | 14 patients (30%); 7 DVT, 3 wound hematomas, 2 arthrofibrosis (1 lysis of adhesions and 1 patella tendon lengthening due to patella baja), 1 delayed wound healing, 1 algodystrophy that spontaneously resolved |
| Naudie et al\textsuperscript{18} | 5 patients (29%); 3 hardware irritation and deep hardware removal, 1 displaced tibial tubercle osteotomy secondary to fall, 1 delayed tibial union |
| Williams et al\textsuperscript{26} | 1 patient (3.8%); postoperative instability on postop day 1                   |
| Badhe and Forster\textsuperscript{2} | 2 patients (14%); 1 deep infection, 1 nonunion                                |
| Neuschwander et al\textsuperscript{19} | 9 patients (47%); 4 extension deficits, 1 DVT, 1 granuloma at tibial osteotomy site, 1 intra-articular fracture, 1 temporary peroneal nerve injury, 1 hardware irritation and deep hardware removal |
| Lattermann and Jakob\textsuperscript{15} | 10 patients (19%); 6 arthrofibrosis (1 manipulation under anesthesia and 5 lysis of adhesions), 2 sensitivity disturbance over scar, 2 revision osteotomy |
| Boss et al\textsuperscript{5}  | 4 patients (10%); 3 revision osteotomies, 1 arthrofibrosis and manipulation under anesthesia |
| O’Neill and James\textsuperscript{22} | 0                                                                            |

\textsuperscript{a}ACL, anterior cruciate ligament; DVT, deep vein thrombosis; PCL, posterior cruciate ligament.
valgus malalignment and chronic medial collateral ligament injuries are needed.

There were some limitations to our study. First, this systematic review included almost entirely level 4 evidence studies consisting of retrospective and prospective case series. Second, despite increased attention of HTO in the ligament-deficient patient, only 2 of the included articles were published in the past 8 years. Additionally, because of the complex injuries of included patients, the reported population was considerably heterogeneous. Furthermore, many of these patients had additional ligament reconstructions performed at the same time or staged so the improvement in outcomes may be related wholly or in part to the ligament reconstructions. While we believe conclusions can be drawn from this study, these 2 factors limit the usefulness of performing a quantitative meta-analysis of the pooled patient data. Therefore, a qualitative analysis was performed. Finally, as there were a large number of articles reviewed, relevant articles may have been missed and inadvertently excluded. We attempted to control for this error with 3 reviewers who independently reviewed each article.

CONCLUSION

High tibial osteotomy has been reported to be useful for the treatment of ligament-deficient knees with significant varus or sagittal plane malalignment. However, there is need for additional high-quality comparative studies in this patient population involving combined HTO and ligament reconstruction versus ligament reconstruction alone.

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