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High tibial osteotomy in knee instability: the rationale of treatment and early results

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Abstract We treated 14 patients having knee instability and varus alignment with tibial osteotomy with or without ligament reconstruction. Five patients with varus angulated anterior cruciate deficiency (double varus) were treated with single-stage closed-wedge tibial osteotomy and anterior cruciate ligament reconstruction. The remaining nine patients had varying amount of posterior cruciate and postero-lateral corner ligament injuries with varus angulation (triple varus); six of these patients had a ligament reconstruction using the Ligament Advanced Reconstruction System ligament with tibial osteotomy (intra-articular–posterior cruciate ligament/extra-articular–postero-lateral corner reconstruction), while the remaining three had a tibial osteotomy without a ligament reconstruction. Four of the nine patients with triple varus had open-wedge tibial osteotomy, and the remaining five had closed-wedge tibial osteotomy. The mean time interval between injury and index surgery of an osteotomy and ligament surgery was 8.3 years (range 1–20 years). At a mean follow-up of 2.8 years after tibial osteotomy, 12 knees (86%) were stable and eliminated of giving way while the remaining 2 were unstable. In one of these patients the result was compromised with severe infection, while in another there was combined cruciate ligament deficiency with postero-lateral corner ligament deficiency. Thirteen (93%) of the patients were able to participate in light recreational activities. None of these patients could return to competitive sports. Five (35%) continued to have pain of varying degree. The mean Cincinnati Knee Score improved from a mean preoperative of 53 (range 40–58) to a mean postoperative of 74 (range 58–82). Accordingly, there were two poor, four fair and eight good results. In-patients with triple-varus, open-wedge tibial osteotomy had better scores than those with closed-wedge procedure. The results of this series are encouraging, and we recommend a high tibial osteotomy along with ligament reconstruction in these complex injuries with varus alignment.

Keywords High tibial osteotomy · Varus osteoarthritis · Anterior cruciate ligament · Postero-lateral corner injury

Introduction

Long-term deficiency of the anterior cruciate ligament (ACL) results in osteoarthritis of the knee [13, 16, 18]. Menisectomy further leads to varus malalignment and development of early osteoarthritis [1, 17]. On the other hand chronic postero-lateral corner ligament injuries causes varus with recurvatum [9]. Thus varus malalignment can be a result of anterior cruciate, postero-lateral

corner ligament deficiency. Reconstruction of these ligaments in presence of malalignment compromises the success of the operation, and recurrence of instability occurs. High tibial osteotomy corrects the varus alignment and offloads the medial compartment [3, 7, 10, 12] and improves the result of ligament reconstruction [10, 19]. Noyes et al. [19] classified these varus deformities on the basis of tibio-femoral alignment, abnormal knee motion limits, abnormal knee joint positions (subluxation) and ligament deficiency:

- Primary varus occurs due to loss of medial meniscus and damage to articular cartilage of tibio-femoral joint leading to varus tibio-femoral alignment [7].
- Double varus occurs due to tibio-femoral varus alignment and separation of the lateral tibio-femoral compartment due to deficiency of lateral soft tissues [15].
- Triple varus occurs due to deficiency of the postero-lateral corner ligament and results in varus with recurvatum. This occurs because of varus osseous alignment (primary varus), separation of lateral tibio-femoral compartment (double varus) and increased external rotation and hyperextension caused by postero-lateral instability [9].

We report our results of ligament reconstruction with high tibial osteotomy in presence of ACL, PCL and postero-lateral corner ligament deficient knee. We further discuss the rationale of open- vs. closed-wedge tibial osteotomy in these complex instabilities.

Material and methods

We reviewed 14 patients with ligamentous instability with varus knees treated with ligament reconstruction and tibial osteotomy during the period of January 1995 to August 2000. There were five women and nine men. Six sustained the injury while playing sports and eight in a road traffic accident. Five had a double varus knee with an ACL deficiency. All the remaining nine patients with triple varus had a postero-lateral corner ligament injury. Five of these patients also had a PCL injury along with a postero-lateral ligament injury.

Twelve patients had a tibial osteotomy as a part of their primary surgery. Of these, nine had a ligament reconstruction along with a tibial osteotomy, while in the remaining three osteotomy was performed as an index primary operation without ligament reconstruction. The remaining two patients had a tibial osteotomy as a secondary procedure after a primary ligament reconstruction. Four patients with triple varus had an open-wedge tibial osteotomy and the remaining patients had a closed-wedge osteotomy. All the patients with ACL deficiency with varus alignment (double varus) had a closed wedge tibial osteotomy and ACL reconstruction using bone–patellar tendon–bone as a single procedure [14]. Of the nine patients with triple varus with postero-lateral ligament injury with/without PCL injury six were treated with tibial osteotomy and ligament reconstruction using Ligament Advanced Reconstruction System–LARS ligament (Arc-Sur-Tille, France) [20] while the remaining three were treated with a primary tibial osteotomy without ligament reconstruction. Three patients had a tibial fracture, one of whom one was treated with an external fixator while the remaining two were treated conservatively. One patient had an ipsilateral femoral shaft fracture, which was treated with an intramedullary nail.

Treatment was as follows:

- Double-varus knee: laterally based closed-wedge upper tibial osteotomy with ACL reconstruction
- Triple-varus knee: postero-anterior based wedge with postero-lateral corner ligament reconstruction

A closed-wedge osteotomy was stabilised with staples and an open-wedge tibial osteotomy with Puddu plates (Arthrex, Germany) along with bone graft from the iliac crest. In open-wedge osteotomy disruption to the proximal tibio-fibular joint was avoided to prevent proximal migration of fibula, causing further postero-lateral laxity. This was not the case, however, in closed-wedge osteotomy and is a drawback of closed-wedge osteotomy in patients with postero-lateral corner ligament instability. One of the ways to avoid this is by leaving the proximal tibio-fibular joint intact and performing a fibular osteotomy.

Postoperatively patients were braced for 6 weeks, and mobilised partial weight bearing was allowed until the osteotomy was united. Patients were advised against returning to competitive sports; however, once quadriceps muscle strength was good, and the knee was stable, they allowed recreational sports.

Outcome was evaluated radiologically and clinically. Clinical evaluation was carried out using the Cincinnati Knee Rating System (CKRS) system [2]. The mean time interval between injury and index surgery of an osteotomy and ligament surgery was 8.3 years (range 1–20 years). The delay in surgery was due predominantly to misdiagnosis of the injury and its severity. All patients were reviewed clinically and radiologically.

Results

Clinical evaluation

At a mean follow-up of 2.8 years (range 51/2 years to 6 months) after a tibial osteotomy 12 knees (86%) were stable. The remaining 2 knees were unstable. One of these patients had severe infection of postero-lateral corner reconstruction postoperatively which resulted in complete disruption of the lateral structures. The other patient with an unstable knee had a combined ACL, PCL and a postero-lateral ligament injury. Both these patients with unstable knees were treated with a closed wedge tibial osteotomy.

The mean CKRS improved from a preoperative mean of 53 (range 40–58) to a postoperative mean of 74 (range 58–82). Patients with double-varus ACL-deficient varus knees treated with closed-wedge tibial osteotomy and ACL reconstruction (Fig. 1) improved from a mean preoperative CKRS of 55 (range 48–58) to a postoperative mean of 80 (range 76–82). Patients with triple varus with postero-lateral ligament with/without PCL injury treated with closed wedge tibial osteotomy and postero-lateral corner reconstruction (Fig. 2) improved from a mean preoperative CKRS of 49 (range 40–56) to a postoperative mean of 65 (range 58–72). However, patients with the same injury (triple varus) treated with open-wedge tibial osteotomy and postero-lateral corner reconstruction (Fig. 3) improved from a mean preoperative CKRS of 55 (range 52–58) to a postoperative mean of 77 (range 72–82). Both patients with poor results were patients with triple varus treated with closed-wedge tibial osteotomy. Three patients

Fig. 1 Antero-posterior radiography showing double-varus knee treated with closed-wedge tibial osteotomy and anterior cruciate ligament reconstruction

Fig. 2 Antero-posterior radiography showing triple-varus knee treated with closed-wedge tibial osteotomy and postero-lateral corner reconstruction

Fig. 3 Antero-posterior radiography showing triple-varus knee treated with medial open-wedge tibial osteotomy and postero-lateral corner reconstruction

with triple deformity treated with osteotomy without ligament reconstruction (Fig. 4) improved with a mean preoperative CKRS of 57 (range 56–58) to a postoperative score of 76 (range 72–78). Accordingly, there were two poor, four fair and eight good results; there were no excellent results (Table 1).

None of these patients returned to competitive sports. However, 13 (93%) could participate in recreational activities. Five patients (35%) continued to experience varying degrees of pain. All of these patients had established osteoarthritic changes.

Radiological evaluation

The mean preoperative mechanical axis deviation in varus was 5° (range 3–11°). Postoperatively this improved to a mean of 6° valgus (range –4° to 11°) Thus one patient had recurrence of varus, one patient an alignment in neutral –0°, and one overcorrection with 11° valgus.

Complications

One patient had infection of postero-lateral corner ligament reconstruction that resulted in complete disruption of lateral tissues. This patient is awaiting a revision ligament reconstruction with allograft tissue. One patient had a non-union of open-wedge tibial osteotomy, which re-

Fig. 4 **A** Antero-posterior radiography showing triple-varus knee treated with antero-medial open-wedge tibial osteotomy without ligament reconstruction. **B** Lateral radiography showing the increase in tibial slope

quired an Ilizarov ring fixator. This osteotomy healed well with good stable knee function.

Discussion

Combined knee instability in the presence of malalignment is a challenging problem for an orthopaedic surgeon. The delay in ligament surgery after injury further complicates the problem. The combination of various ligament injuries presents diagnostic dilemma and hence, for the reasons stated above, the treatment becomes even more difficult.

None of the cases in this series were similar to each other. The small number of patients in the series along with a heterogeneous population of patients with double- and triple-varus deformity and varying treatment modalities used various ligament reconstructions, including ACL, postero-lateral ligament and PCL reconstruction along with osteotomy (open wedge vs. closed wedge) precludes the drawing of definitive conclusions. However, there are certain trends which do suggest the rationale of treatment in these complex instabilities with varus malalignment.

The injuries in our series were complex, and the purpose of treatment was to allow patients symptom-free activities of daily living and light recreational activities, and competitive sports was an unrealistic goal. Preoperatively all of the patients with triple varus were using braces for activities of daily living, and none was involved in any form of recreational activities.

Varus aligned knee compromises the results of ligament reconstruction. In ACL-deficient knee it leads to progression of osteoarthritis because of increased anterior tibial translation on weight bearing [6]. Anterior tibial

Table 1 Patient demographics, details of treatment and results of tibial osteotomy with/without ligament reconstruction in knee instability (*CKRS* Cincinnati Knee Score, *RTA* road traffic accident, *O-Hto* open-wedge tibial osteotomy, *PCL* posterior cruciate ligament, *PLRI* postero-lateral rotatory instability, *ACL* anterior cruciate ligament, *DV* double varus, *TV* triple varus)

Patient-no.	Sex	Age (years)	Mec. injury	Int. injury (years)	Instability	First treatment	Second treatment	Follow-up (years)	CKRS preop.	CKRS postop.	Compl.	Result
1	M	37	RTA	17	ACL (DV)	Hto+ACL	–	1.5	56	76	–	G
2	F	18	RTA	2	ACL (DV)	Hto+ACL	–	5	57	76	–	G
3	F	40	RTA	11	ACL (DV)	Hto+ACL	–	1	54	80	–	G
4	F	32	RTA	4	ACL (DV)	Hto+ACL	–	2	50	80	–	G
5	M	65	Sport	1.5	ACL (DV)	Hto+ACL	–	5.5	58	80	–	G
6	M	32	Sports	11	PCL+PLRI (TV)	Hto+PCL+PLRI	–	3.5	50	68	–	F
7	M	30	Sports	1	ACL+PLRI (TV)	Hto+ACL+PLRI	–	3.5	48	66	–	F
8	M	32	RTA	2	ACL+PLRI (TV)	ACL+PLRI	O-Hto	1	56	72	–	F
9	F	30	Sports	2	PCL+PLRI (TV)	O-Hto+PCL+PLRI	–	2	52	82	–	G
10	M	40	RTA	20	ACL+PCL+PLRI (TV)	Hto+PCL+PLRI	–	4.5	40	64	–	P
11	F	32	RTA	1	PLRI (TV)	HTO+PLRI	Awaiting revision	3	52	58	Infn.	P
12	M	33	Sports	4	PCL+PLRI (TV)	O-Hto	–	2	58	78	Non-union	G
13	M	35	Spots	20	PCL+PLRI (TV)	O-Hto	–	0.5	56	78	–	G
14	F	38	RTA	2	PLRI (TV)	Hto	–	5	56	72	–	F

translation depends on various factors: the ACL, posterior horn of medial meniscus, posteromedial capsule and posterior slope of the tibia. Bonnin [4] states that the load to tibial translation in ACL-deficient knee is three times greater if the slope of tibia exceeds 10° than when it was less than this in unilateral weight bearing. Hence Bonnin [4] and Dejour et al. [5] advocate an antero-lateral closed-wedge osteotomy in patients with posterior tibial slope of more than 10° in a double-varus knee. The converse is true for PCL-deficient knees and an increase in slope of tibia improves the function of PCL reconstruction and corrects the recurvatum in a triple varus knee (Fig. 4). Noyes et al. [22] further state that in a varus-angulated ACL-deficient knee there were high adduction movements of the knee which cause increased medial compartment loading and high stresses on the lateral ligament complex. This forms the basis of the rationale of tibial osteotomy in varus aligned knees with instability.

Dugdale and Noyes et al. [7, 19] advocate that following a tibial osteotomy the weight-bearing axis of the lower limb should pass through the 62% coordinate of the width of the tibial plateau (0% corresponds to medial border of tibial plateau and 100% corresponds to lateral border). They further state that overcorrection of valgus should be avoided by taking into consideration the lateral tibio-femoral opening due to laxity of the lateral structures. (Subtract 1° for 1 mm lateral opening.) However, they advocate that the mechanical axis be corrected to neutral in patients with normal medial compartment and articular cartilage, without valgus overcorrection. The purpose of alignment surgery in these patients is to reduce the varus thrust and reduce the stresses on the lateral ligament on weight bearing.

Preservation of the proximal tibio-femoral joint is essential as it maintains the normal tension in the postero-lateral ligament by preventing proximal migration of the fibula. The medial opening wedge tibial osteotomy has this added advantage. It does not disrupt the proximal tibio-fibular joint, corrects medial laxity, corrects larger varus angulation (>12°) and prevents patella baja. However, it has the added morbidity of bone grafting along with possibility of non-union.

All our five patients with an ACL-deficient varus knee (double-varus knees) had a single-stage closed-wedge lateral tibial osteotomy with ACL reconstruction using bone patellar tendon. In the remaining nine patients with postero-lateral ligament deficient knee with or without a PCL deficiency (triple varus), five had a lateral closed-wedge tibial osteotomy, while the remaining had a medial open-wedge tibial osteotomy. Of the nine patients with triple-varus deformity six had a LARS postero-lateral ligament (extra-articular) with or without PCL reconstruction (intra-articular), while the remaining three had a tibial osteotomy without a ligament reconstruction. Thirteen patients had an osteotomy as a part of primary surgery while in one patient it was performed as a secondary procedure.

Noyes et al. [19] advocate a staged operative procedure for triple varus for the fear of postoperative complications. They allow the osteotomy to heal and then perform an arthroscopic ACL reconstruction and an open postero-lateral corner ligament reconstruction. However, we perform simultaneous osteotomy with stabilisation and ligament reconstruction in ten patients. One patient had an infection, which compromised the result of postero-lateral ligament reconstruction and is awaiting revision surgery. In one patient the open-wedge tibial osteotomy did not heal and required an Ilizarov ring fixator to achieve union. This, however, did not compromise the result, and the patient has a stable knee.

Deficiency of postero-lateral structures was determined clinically by varus recurvatum deformity of knee (triple varus), increased lateral joint space and increased tibial external rotation and arthroscopy revealing increased lateral joint space (>12 mm at periphery) [19, 20]. In all our cases of triple varus there was complete deficiency of postero-lateral structures and hence no form of proximal advancement procedure was performed in these patients. Six of these patients had a LARS ligament reconstruction and the remaining three a tibial osteotomy without ligament reconstruction.

One patient in our series had a recurrence of varus and one had overcorrection with increased valgus. The reported rate of recurrence of varus after a high tibial osteotomy varies from 11% to 45% [8, 15, 21]. Subtracting that component of varus alignment that occurs due to lateral joint opening caused by lateral ligament failure can prevent valgus overcorrection.

Noyes et al. [19] had in their series 41 patients with varus-angulated ACL-deficient knee with varying amount of postero-lateral corner ligament deficiency. All of these were treated with tibial osteotomy and ACL reconstruction, and 18 had postero-lateral ligament reconstruction. Twenty-seven patients (66%) resumed recreational activities, and 29 patients (71%) rated their knee as good, with a reduction in pain in 29 knees (71%). Dejour et al. [5] in their series of 44 knees treated with ACL reconstruction and valgus tibial osteotomy had 26 patients (59%) who could play leisure sports, and 37 patients (91%) were satisfied with their operation.

In our series of 14 patients with varus-angulated ACL/postero-lateral corner ligament deficient knee five were treated with ACL reconstruction and six with LARS postero-lateral ligament reconstruction with a tibial osteotomy. The remaining three patients were treated with a tibial osteotomy without ligament reconstruction. Twelve knees (86%) were stable, and the patients were able to participate in leisure sports, while the remaining two knees were unstable, with one patient using a brace and another awaiting revision surgery. Five patients (35%) continue to experience pain in their knees of varying degree. All of these patients have established arthritic changes on radiography. The mean CKRS improved from

a preoperative mean of 53 (range 40–58) to a postoperative mean of 74 (range 58–82). Patients with triple-varus open-wedge tibial osteotomy had better scores than those with closed-wedge procedure. Accordingly, there were two poor, four fair and eight good results.

As the number of patients in our series was small, and the series was a non-homogeneous group with knee instability, definitive conclusions cannot be drawn, and a much larger group of patients with long-term follow-up is necessary. However, there are definite trends in these patients:

- Varus-angulated ACL-deficient knees (double varus) do well with single-stage closed-wedge tibial osteotomy and ACL reconstruction.
- Varus-angulated postero-lateral ligament deficient knees (triple varus) do better with open-wedge tibial osteotomy than with closed-wedge tibial osteotomy and ligament reconstruction without disturbing the proximal tibio-fibular joint.
- If postero-lateral structures are lax and not completely disrupted, an opening wedge tibial osteotomy without ligament reconstruction tends to stabilise the knee and avoid ligament reconstruction.
- The chronicity of injuries with previous surgeries and the increased interval between injury and index surgery tend to compromise results of these surgery, as an incomplete lateral ligament injury with varus alignment will eventually lead to complete disruption because of the varus thrust gait. On the other hand, an early high tibial osteotomy alone in these patients allows physiological remodelling and shortening of these structures [22].

The diagnosis of these injuries is difficult and is often missed, which precludes early intervention. With increasing experience we hope we will be able to treat these injuries early and improve their prognosis. One must stress, however, that these injuries, i.e. double-varus and triple-varus knees, are serious injuries, and that the aim of surgery is to achieve a stable knee, compliant with activities of daily living and leisure sports, and not return to competitive sports and patients should be counselled regarding this prior to contemplating surgery.

The results of our series along with those of other authors [15, 19] are encouraging. However, long-term follow-up with increased number of patients is essential to determine whether the outcome of these injuries is altered by our treatment.

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