High tibial osteotomy: back to the future

High tibial osteotomy was once a popular surgical treatment for isolated medial compartment osteoarthritis of the knee. Although largely superseded by prosthetic arthroplasty for this purpose, exciting new applications for the procedure have recently developed, which will be discussed below.

From its origins in the correction of deformities caused by polio, rickets and trauma the high tibial osteotomy developed in the 1960s as an effective treatment for uni-compartmental osteoarthritis of the knee. However, the success of knee arthroplasty has narrowed the indications for the procedure to a physiologically younger, active group of patients, for whom prosthetic joint replacements do not provide an attractive long-term solution.

Despite this, renewed interest has occurred recently as new applications in the management of ligament instability and in conjunction with chondral resurfacing have become apparent. Better understanding and modern fixation techniques have led to improved clinical results, and in addition the numbers of younger patients with uni-compartmental arthritis are increasing.

The use of the high tibial osteotomy is rapidly evolving, and this article will define its role in modern orthopaedic practice.

History

The first recorded use of tibial osteotomy for uni-compartmental osteoarthritis of the knee in modern English literature comes from Jackson (1958). They described an osteotomy sited just below the tibial tuberosity to correct varus or valgus deformities. In a series of ten patients treated by this method all were relieved of pain.

However, it was not until Coventry (1965) that the operation gained widespread recognition as a treatment for isolated medial compartment arthritis. He popularized the lateral closing wedge osteotomy performed above the tibial tubercle in an attempt to add stability.

The advantages of Coventry's high tibial osteotomy are that it is made nearer the deformity and resects cancellous metaphyseal bone which heals rapidly. This approach also allows the quadriceps muscle to exert a compressive effect at the osteotomy site, thus aiding stability and allowing immediate weight-bearing.

Mr Shahid Punwar *is Orthopaedic Research Fellow and* **Mr Fares S Haddad** *is Consultant Orthopaedic Surgeon, Department of Orthopaedic and Trauma Surgery, University College London Hospital, London NW1 2BU*

Correspondence to: Mr S Punwar

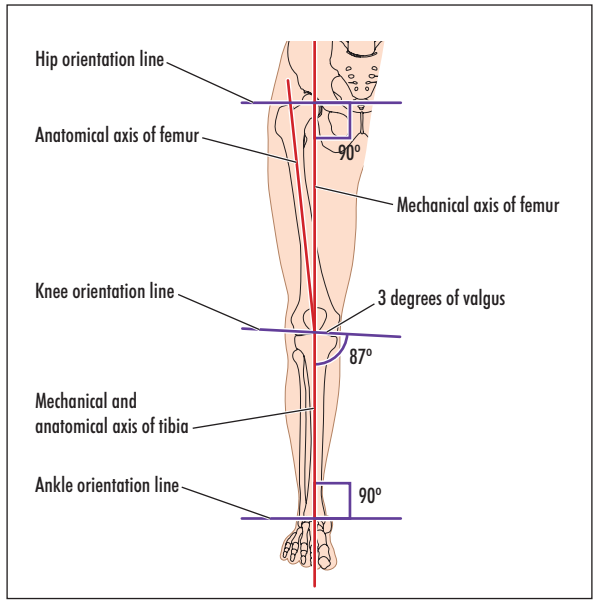
Principles

The anatomical axis of the lower extremity is defined by the tibiofemoral angle, which averages 5° of valgus. The mechanical (weight-bearing) axis of the lower extremity is defined by a plumb line connecting the centre of the femoral head to the mid ankle on a standing anteroposterior (AP) weight-bearing radiograph. The mechanical axis is classically taken as 0° in the AP plane, and is more accurate than the anatomical axis in demonstrating load transmission across the knee joint (*Figure 1*).

Varus or valgus deformities of the tibia are common and cause an abnormal distribution of the weight-bearing stresses within the joint. If the deformity is one of varus position, stresses are concentrated medially accelerating degeneration in that compartment. If the deformity is valgus the same applies to the lateral compartment, though this is much less common.

Operations to reshape the tibia (osteotomy) aim to unload diseased articular surfaces by correcting angular deformity at the tibiofemoral articulation, restoring

Figure 1. Normal alignment of the lower limb.



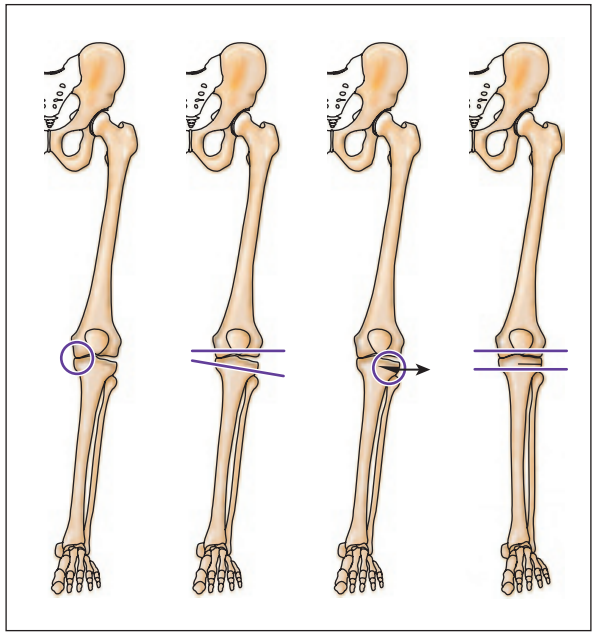


Figure 2. Restoration of a horizontal joint line.

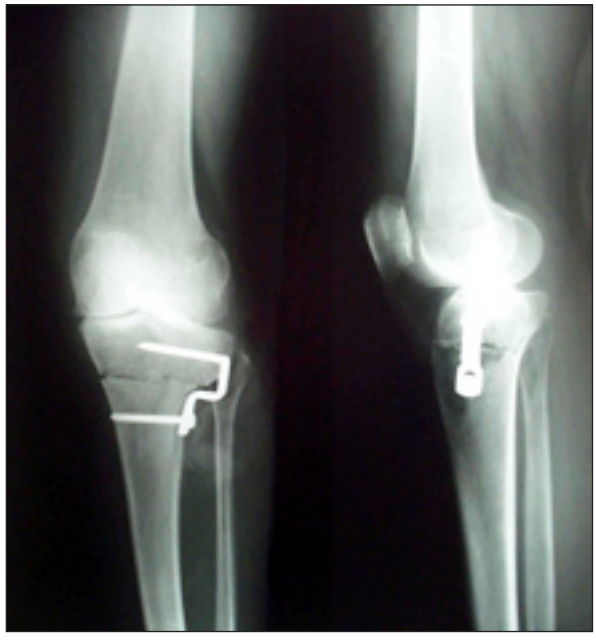


Figure 3. Example of a lateral closing wedge osteotomy.

the normal mechanical axis and a horizontal joint line (*Figure 2*).

As well as slowing further damage and relieving pain, there is also some evidence that osteotomy facilitates the natural reparative capacity of the knee joint. Articular cartilage regeneration and fibrocartilage proliferation has been demonstrated during repeat arthroscopy, compared to prior arthroscopic findings in knees following the procedure (Odenbring et al, 1992). In this way osteotomy can be considered a biological solution to joint degeneration, as it aims to help the body heal itself by eliminating the cause of the problem, without resorting to prosthetic joint arthroplasty.

Although correction of the mechanical axis has a sound theoretical basis, it must be remembered that it only represents a static model of weight bearing. Modern gait analysis has shown that there is significant tibial adduction moment during walking, and it is likely that the reduction of this force following osteotomy contributes to the overall results.

Types of osteotomy

Closing wedge

The lateral closing wedge technique (*Figure 3*) involves removing a segment of bone and then closing the resulting cortical gap. The angle of resection is planned from the preoperative radiographs and determined intraoperatively with fluoroscopy. The medial cortex or hinge is then left intact and the osteotomy is fixed. Originally fixation was by staples followed by 6–8 weeks of cast immobilization, but there are now a number of different methods available, including screws and plates. Modern rigid fixation methods allow earlier full weight bearing and more rapid rehabilitation. Although conventionally the bone cuts are made free-hand, there are now jigs available to provide more accurate correction (Hofmann et al, 1991). The closing wedge type is the most stable form of osteotomy and has the highest union rate.

In closing wedge osteotomy the proximal tibiofibular joint will prevent angular correction unless the fibula is shortened or the tibiofibular ligaments are removed. There are basically three ways to do this. The first is division of the proximal tibiofibular joint, which allows the head to slide proximally; however, this may risk loosening of the lateral collateral ligament. Alternatively the fibula may be obliquely transected in its proximal third to allow overlap as the osteotomy is closed, or the fibula head may be resected completely. In all cases care should be taken to avoid the common peroneal nerve as it winds around the fibular neck.

Opening wedge

A logical alternative to creating a valgus tibia by a lateral closing wedge osteotomy is to utilize a medial opening wedge technique.

In France, medial opening wedge high tibial osteotomy has been used to treat medial compartment osteoarthritis since 1951 (Hernigou et al, 1987). This technique has the advantage that the lateral soft tissues, fibula and peroneal nerve are left undisturbed, the limb is not shortened and patello-femoral function is not altered. Bone graft is usually interposed in the open wedge, and fixation is with internal distraction plates or external fixators.

Because of the array of sizes of distraction plates and the ability to control the amount of callus distraction (hemicallotasis) with a dynamic external fixator (*Figures 4* and *5*), it is technically easier to attain the precise desired degree of angular correction, compared to the closing wedge high tibial osteotomy.

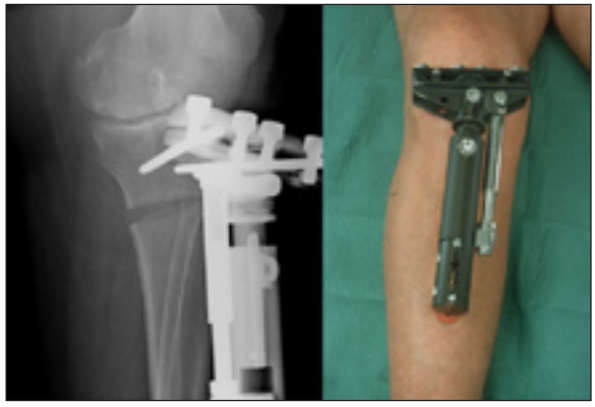
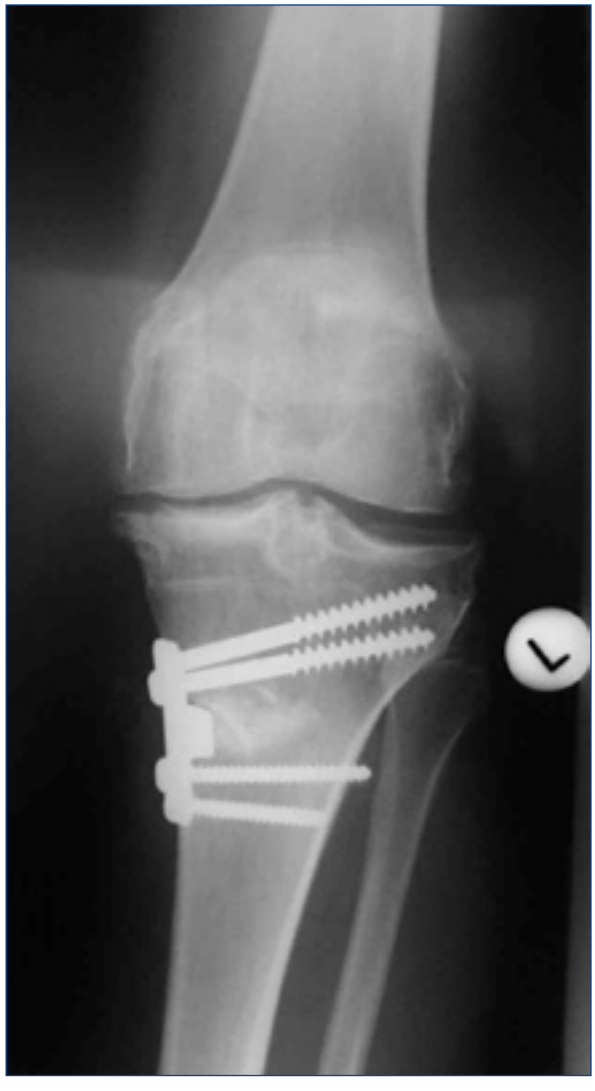


Figure 4. Example of an external fixator used in opening wedge high tibial osteotomy.

Dome or barrel vault

The third type of osteotomy in common use is the dome osteotomy described by Maquet (1976). This technique involves anterior displacement and rotation of the proximal tibia rather than removal of a wedge of bone to correct the deformity. Theoretically the dome osteotomy can relieves stress on the patello-femoral as well as the affected tibio-femoral compartment; however, it is technically difficult and fraught with complications.

Figure 5. Radiograph of medial opening wedge high tibial osteotomy with distraction plate fixation.



Complications of tibial osteotomy

Bony

Delayed union or non-union is possible, as with all osteotomies. The chances of these can be minimized by making neat opposing cuts through the bone to allow maximum bony contact, and by adequate fixation after operation.

Non-union is uncommon after closing wedge high tibial osteotomy because of the excellent healing potential of the two metaphyseal cancellous surfaces that are in stable, direct apposition. This is a distinct advantage of the closing wedge over the opening wedge technique, in which healing must traverse an intercalary segment of autograft or allograft.

Propagation of the bony cuts through the opposing cortex in wedge osteotomy is undesirable, because the proximal fragment will be destabilized. Intra-articular fracture is an even more severe complication. The risk of both can be minimized by carrying the apex of the osteotomy cut to within 10 mm of the far cortex and leaving the proximal fragment at least 15 mm thick. In addition the osteotomy should always be opened or closed gradually to avoid damage to the far cortex.

Avascular necrosis of the proximal fragment may result from too shallow a cut and a proximal fragment that is too thin.

Patella height

Lateral closing wedge high tibial osteotomy has been associated with a high incidence of postoperative lowered patella height (patella baja) supposedly because the distance between the tibial tubercle and the patella is decreased, creating laxity in the patellar tendon, which subsequently shortens. This is undesirable because of the association between anterior knee pain and patella baja as well as the increased difficulty of subsequent conversion to a total knee replacement.

However, current thinking is that the lowered patella height found in closing wedge high tibial osteotomy results from contraction of the patella ligament as a result of prolonged cast immobilization. This tendon contracture can be eliminated by the use of rigid internal fixation and aggressive postoperative mobilization (Hoffman et al, 1991).

Neurovascular

The incidence of peroneal palsy following lateral closing wedge high tibial osteotomy ranges from none to 20% (Wright et al, 2005), and may have several causes. The nerve may be injured directly during operation or by the pressure of a tight plaster or bandage.

Vascular complications are rare, but the anterior tibial artery can be compromised and an anterior compartment syndrome may ensue. Use of a drain at the incision site has been shown to decrease anterior compartment pressures.

Inadequate correction

Failure to reach the desired degree of correction is largely a technical issue, and can be avoided by accurate preoperative measurements and calculation of the osteotomy wedge size. However, axial alignment may be lost over a period of years after osteotomy, as a result of continued medial wear and lateral ligament laxity. To some extent this may be prevented by initial over-correction and by intervention early in the disease process.

Infection

The incidence of deep infection after lateral closing wedge osteotomy ranges from none to 4% (Wright et al, 2005). Superficial infections are common with medial opening wedge high tibial osteotomy techniques that involve the use of an external fixator; pin tract infections have been reported in as many as 25–50% of these patients. These infections typically remain superficial and respond favourably to pin care and oral antibiotics.

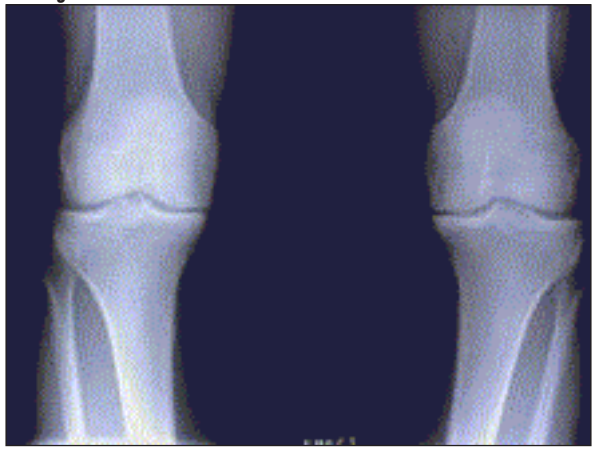
Applications

Osteoarthritis

For decades proximal tibial osteotomy has been used to treat uni-compartmental osteoarthritis of the knee in younger, active patients. Uni-compartmental and total knee replacements yield more predictable and durable results, yet both are generally restricted to older, less active patients because of component wear and the need for revision.

Rehabilitation following tibial osteotomy can be lengthy (10 weeks), whereas in contrast total knee replacement gives almost immediate mobility and pain relief. To the elderly patient the advantage of replacement is obvious.

Figure 6. Bilateral medial compartment osteoarthritis with varus malalignment.



Most studies have shown satisfactory results in about 80% of patients at 5 years and 60% at 10 years after closing wedge high tibial osteotomy (Coventry et al, 1993). Favourable outcomes are associated in patients under 60 years of age, with purely uni-compartmental disease, stable ligaments, low body weight and a preoperative range of motion of at least 90°.

Preoperative preparation for osteotomy involves determining the amount of correction to be obtained. At present the only reliable indicator is the standing radiograph from which measurements of the tibiofemoral angle are made. Based on regression analysis Coventry advocated correction not only to normal, that is 5–7° of anatomical valgus angulation (or 0° of mechanical axis), but also to overcorrect it to 8–10°. Other groups have also reported good follow-up results with correction of only 3–6° valgus (Hernigou et al, 1987).

The indications for high tibial osteotomy in osteoarthritis are debilitating pain consistent with radiographical evidence of uni-compartmental disease and a corresponding varus or valgus deformity (*Figure 6*). Patients should be able to use crutches after the operation and possess sufficient muscle strength and motivation to carry out a rehabilitation programme.

Apart from the prerequisite for uni-compartmental disease, principal contraindications to high tibial osteotomy are non-concordant pain (i.e. patellofemoral pain with medial compartment osteoarthritis), inflammatory arthritis, obesity and patient unwillingness to accept the expected cosmetic appearance of the required angular correction.

The key requirements for success appear to be patient selection and good operative technique. However, as the results of high tibial osteotomy inevitably deteriorate, the eventual need for joint arthroplasty should always be remembered. Although it is generally agreed that conversion to a total knee replacement following high tibial osteotomy is more technically difficult than a primary total knee replacement, most studies have found only slightly inferior functional outcomes at follow up (Haddad and Bentley, 2000).

Brouwer et al (2005) conducted a Cochrane review on the use of osteotomy for treating knee osteoarthritis. After reviewing the available literature they only included 11 quality studies in their article based on objective criteria including the use of blinding and randomization. All 11 studies concerned valgus high tibial osteotomy for medial compartment osteoarthritis of the knee. They found comparison between studies difficult because of the use of different techniques, comparison treatments and a variety of outcome measures. Overall the authors concluded that there is no evidence whether osteotomy is more effective than conservative treatment, and furthermore no clear indication which type of osteotomy is the most effective. They did concede that valgus high tibial osteotomy can improve knee function and reduce pain, but indicated a clear need for further well designed studies in this area.

Owing to the rarity of isolated lateral compartment disease, varus-producing osteotomies for lateral compartment osteoarthritis have received scant attention. However, most authorities have expressed a preference for performing a varus producing distal femoral osteotomy, rather than a tibial procedure in this setting.

Chondral resurfacing and soft tissue surgery

Over the past decade surgical techniques have been developed aimed at treating isolated defects of knee articular cartilage (*Figure 7*). These include abrasion and microfracture, marrow stimulation, autologous chondrocyte implantation, osteochondral autograft transplantation and autogenous periosteal grafting. Proponents of each of these techniques emphasize that associated joint malalignment is a contraindication to performing these procedures (Minas, 2000).

Malalignment subjects the intended repair tissue to mechanical overload, and should either be corrected simultaneously with resurfacing or as a staged procedure.

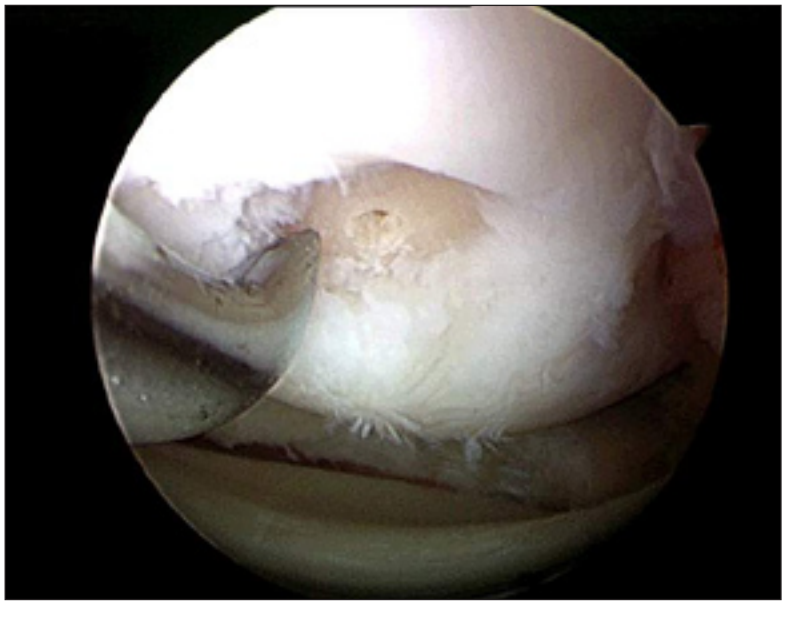
Whether high tibial osteotomy improves on the result of chondral resurfacing, or whether chondral resurfacing improves on the result of the high tibial osteotomy, is a subject of debate. It is likely that each procedure has a synergistic effect leading to an overall better clinical outcome.

For similar reasons high tibial osteotomy should be considered as an adjunct to soft tissue procedures (e.g. anterior cruciate ligament reconstruction) in the presence of malalignment. Uncorrected alignment leads to repetitive stresses and eventual failure of the surgically reconstructed structures, producing poor results.

Instability

Traditionally knee instability was considered a contraindication to high tibial osteotomy because it was associated with less satisfactory clinical results (Coventry et al, 1993). However, these findings were from patients whose primary problem was osteoarthritis, not patients undergoing osteotomy primarily for instability.

Figure 7. Articular cartilage defect of the medial femoral condyle.



The realization that uncorrected alignment places high stresses on reconstructed soft tissues has led to the increasing use of osteotomies in conjunction with ligament reconstruction techniques.

In addition a growing number of patients have both anterior knee instability secondary to anterior cruciate ligament deficiency, and unilateral degenerative joint disease with varus malalignment. A large majority of these patients report a history of previous medial meniscal injury or meniscectomy after knee trauma at a relatively young age, contributing to the varus deformity and accelerating cartilage wear.

Lattermann and Jakob (1996) found that in those patients aged 40 years or older high tibial osteotomy alone is an excellent treatment option with reproducibly good results. The same study concluded that in younger, active patients high tibial osteotomy should be performed first, and then if instability persists anterior cruciate ligament reconstruction should be performed at a 6–12-month interval. Although some advocate a combined procedure, it is not only difficult to assess the individual effect of each procedure, but also the complication rate and rehabilitation period is inevitably increased.

While we understand why correcting alignment in the frontal plane may alleviate uni-compartmental osteoarthritis, the reasons why high tibial osteotomy should affect anteroposterior stability have previously been unclear. Investigation into the contribution of sagittal plane deformity to knee stability has provided some possible answers.

In a biomechanical study, Bonnin (1990) found the load on the anterior cruciate ligament to be greater when the posterior slope of the tibia exceeded its normal value of 10° posterior inclination during weight bearing. In a subsequent radiographical analysis of 281 cases, Dejour and Bonnin (1994) noted a linear correlation between the tibial slope and tibial translation during monopedal weight bearing. Together, these authors theorized that decreasing posterior tibial slope in the sagittal plane decreases the anteroposterior component of the joint contact forces and reduces anterior subluxation of the tibia relative to the femur, thus improving symptoms of anterior instability. Conversely, they theorized that increasing posterior tibial slope increases the anteroposterior component of the joint contact forces and reduces posterior subluxation of the tibia relative to the femur, thus improving symptoms of posterior instability (*Figure 8*).

Several follow-up studies suggest that lateral closing wedge osteotomies tend to decrease posterior tibial slope, whereas medial opening wedge osteotomies tend to increase tibial slope. This has led to the idea of using

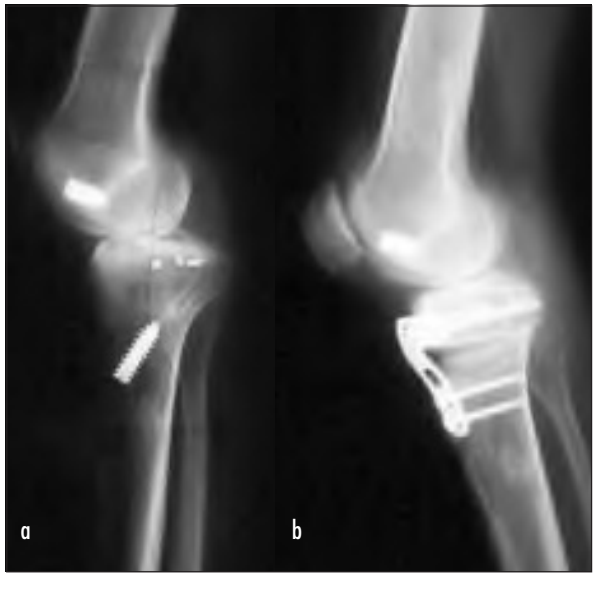
lateral closing wedge high tibial osteotomies for patients with chronic anterior cruciate ligament-deficient knees and medial opening wedge procedures for symptoms of posterior instability.

At present very few recommendations have been made regarding optimal correction of the tibial slope, but research is ongoing. It seems logical that alignment should be tailored to the individual patient's requirements.

Conclusions

The high tibial osteotomy originally evolved following similar procedures at the hip. While established in the treatment of uni-compartmental arthritis, the procedure faces stiff competition from prosthetic knee arthroplasty, and its use may be reserved for a specific cohort of young, active patients. As recreational sports and injuries increase it is likely that this young cohort will expand. Unlike prosthetic joint replacements high tibial osteotomy imposes no permanent activity restrictions, and allows the preservation of bone stock for future operations.

Figure 8. a. Lateral radiograph showing posterior subluxation of the tibia following failed posterior cruciate ligament reconstruction. b. Lateral radiograph following opening wedge osteotomy showing resolution of posterior subluxation.



Beyond osteoarthritis tibial osteotomy is gaining popularity in the management of complex knee instability, by allowing alterations of the sagittal tibial slope. This is an exciting development and it is evident that further studies are required in this area. **BJHM**

Figure 4 *is reproduced with permission from Dahl et al (2005).*

Conflict of interest: none.

Bonnin M (1990) La subluxation tibiale anterieure en appui monopodal dans les ruptures du ligament croise anterior: Etude clinique et bio-mechanique. Thesis. Universite Claude Bernard, Lyon, France

Brouwer RW, Jakma TSC, Bierma-Zeinstra SMA, Verhagen AP, Verhaar J (2005) Osteotomy for treating knee osteoarthritis. The Cochrane Database of Systematic Reviews Issue 1. Art. No.: CD 004019. pub2

Coventry MB (1965) Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. *J Bone Joint Surg Am* **47:** 948–90

Coventry MB, Ilstrup DM, Wallrichs SL (1993) Proximal tibial osteotomy. A critical long-term study of eighty-seven cases. *J Bone Joint Surg Am* **75:** 196–201

Dahl A, Toksvig-Larsen, Roos EM (2005) A 2 year prospective study of patient relevant outcomes in patients operated on for knee osteoarthritis with tibial osteotomy. *BMC Musculoskelet Disord* **6**(1): 18

Dejour H, Bonnin M (1994) Tibial translation after anterior cruciate ligament rupture: Two radiological tests compared. *J Bone Joint Surg Br* **76B:** 745–9

Haddad F, Bentley G (2000) Total knee arthroplasty after high tibial osteotomy: a medium-term review. *J Arthroplasty* **15**(5): 597–603

Hernigou P, Medevielle D, Debeyre J, Goutallier D (1987) Proximal tibial osteotomy for osteoarthritis with varus deformity. *J Bone Joint Surg Am* **69:** 332–54

Hofmann AA, Wyatt RW, Beck SW (1991) High tibial osteotomy: Use of an osteotomy jig, rigid fixation, and early motion versus conventional surgical technique and cast immobilization. *Clin Orthop Relat Res* **271**: 212–17

Jackson JP (1958) Osteotomy for osteoarthritis of the knee. In Proceedings of the Sheffield Regional Orthopaedic Club. *J Bone Joint Surg Br* **40-B**(4): 826

Lattermann C, Jakob RP (1996) High tibial osteotomy alone or combined with ligament reconstruction in anterior cruciate ligament-deficient knees. *Knee Surg Sports Traumatol Arthrosc* **4**(1): 32–8

Maquet PGJ (1976) *Biomechanics of the Knee with Application to the Pathogenesis and the Surgical Treatment of Osteoarthritis.* Springer-Verlag, Berlin

Minas T (2000) A practical algorithm for cartilage repair. *Oper Tech Sports Med* **8:** 141–3

Odenbring S, Egund N, Lindstrand A, Lohmander LS, Willen H (1992) Cartilage regeneration after proximal tibial osteotomy for medial gonarthrosis: an arthroscopic, roentographic, and histologic study. *Clin Orthop* **277:** 210–16

Wright JM, Crockett HC, Slawski DP, Madsen MW, Windsor RE (2005) High tibial osteotomy. *J Am Acad Orthop Surg* **13**(4): 279–89

KEY POINTS

- High tibial osteotomy aims to correct malalignment and mechanically unload diseased articular cartilage.
- It is established in uni-compartmental osteoarthritis of the knee, but its use is declining because of the success of prosthetic knee arthroplasty.
- Renewed interest in the technique has occurred recently as new applications in instability and in conjuction with chondral resurfacing have developed.