International Orthopaedics (SICOT) (2010) 34:173–184
DOI 10.1007/s00264-009-0883-1

REVIEW

Closing wedge osteotomy of the tibia and the femur in the treatment of gonarthrosis

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Received: 31 August 2009 / Revised: 16 September 2009 / Accepted: 16 September 2009 / Published online: 15 October 2009

Abstract New developments in osteotomy techniques and methods of fixation have caused a renewed interest in closing wedge osteotomies of the tibia and femur in the treatment of gonarthrosis. The rationale, definition and techniques of closing wedge tibial and femoral osteotomies in the treatment of gonarthrosis are discussed. The principal indications include unicompartmental medial and much less so, varus knee gonarthrosis and unicompartmental lateral or valgus knee gonarthrosis with a well-maintained range of motion in patients who are physiologically young. Newer techniques have provided more rigid fixation and improved accuracy of correction.

Introduction

Osteotomies of the proximal tibia and the distal femur have been used for more than a century to correct angular deformity in the setting of rickets, poliomyelitis, posttraumatic conditions and congenital conditions. Jackson is credited with being the first in the English-language literature to report a high tibial osteotomy to treat gonarthrosis of the knee, a below-the-tibial tubercle proximal osteotomy [1]. Coventry et al. [2] and Insall et al. [3] popularised the above-the-tubercle proximal lateral closing wedge high tibial osteotomy in the United States during the 1960s.

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The normal anatomical load-bearing axis of the knee ranges from 5 to 7 degrees of valgus. In a normal knee approximately 60% of the weight-bearing force is transmitted through the medial compartment and 40% through the lateral compartment [4].

Medial or varus gonarthrosis is common. Varus alignment causes additional force on the medial compartment. For varus gonarthrosis, the main options include proximal tibial lateral closing wedge osteotomy, proximal tibial medial opening wedge osteotomy, dome osteotomy or combinations of the above. The goal is to shift the mechanical axis laterally therefore offloading the medial compartment, traditionally at 62–66% of the tibial width [5, 6].

Lateral or valgus gonarthrosis is less common. Valgus alignment causes additional force on the lateral compartment. For valgus gonarthrosis, the main options include distal femoral medial closing wedge osteotomy, distal femoral lateral open wedge osteotomy or proximal tibial medial closing wedge osteotomy. The goal in valgus gonarthrosis is to shift the mechanical axis medially therefore offloading the lateral compartment.

Our review will focus on closing wedge osteotomies of the tibia and femur for the treatment of gonarthrosis. Both tibial and femoral osteotomies can be classified as valgus or varus producing. The goals of osteotomy are to relieve pain, to redistribute weight-bearing forces, to improve function and thereby potentially increase the longevity of the native knee joint.

Indications for closing wedge osteotomies in the treatment of gonarthrosis

The ideal patients for osteotomies are the physiologically young and active patients who have unicompartmental

knee gonarthrosis and are therefore not optimal candidates for total knee replacement. However, one should always consider osteotomy in the older than 60 years population with unicompartmental disease who are capable and desire to participate in high-impact physical activities. Patients younger than 65 years of age do typically rehabilitate faster than older patients after osteotomy; however, there is no age limit for osteotomy and patients should not be excluded from consideration based on chronological age alone [5, 7, 8].

Contraindications for closing wedge osteotomies in the treatment of gonarthrosis

The principal contraindications for valgus-producing osteotomies are lateral compartment degenerative joint disease, loss of a significant portion of the lateral meniscus, fixed flexion deformity of more than 15 degrees, or gross varus knee deformity or instability. Keene and Dyreby reported that the presence of mild lateral compartment deterioration noted during preoperative arthroscopy did not compromise the initial success of lateral closing wedge proximal tibial osteotomy; however, their short follow-up of two to three years must be considered when evaluating these conclusions [9]. Mild lateral compartment chondromalacia may not be an absolute contraindication to a valgus-producing osteotomy, but advanced lateral compartment degeneration certainly is a contraindication.

The principal contraindications for varus-producing osteotomies are medial compartment degenerative joint disease or loss of a significant portion of the medial meniscus. Relative contraindications for varus-producing osteotomies are anteroposterior knee instability, excessive lateral bone loss causing valgus instability of the knee and limitation of flexion to less than 80 degrees and loss of extension of more than 20 degrees [7, 8, 10, 11]. An adduction contraction of the ipsilateral hip is a specific contraindication because the contracture produces valgus stress about the knee, which will lead to recurrence of the deformity [7, 10]. It is important to remember that varus closing wedge tibial osteotomy produces an increase in the joint line obliquity; therefore, if the joint line is not parallel to the ground in the standing position, a varus closing wedge osteotomy of the tibia should not be considered.

Contraindications for either a valgus or varus producing osteotomy are symptomatic patellofemoral degenerative joint disease, non-concordant pain (e.g. significant anterior knee pain with medial degenerative joint disease on X-rays), patient unwillingness to accept the anticipated cosmetic appearance for the angular correction, patient unwillingness to be compliant with postoperative restrictions, and inflammatory arthritis. Mild patellofemoral degeneration is not an absolute contraindication for either a varus or valgus producing osteotomy; however, significant symptomatic patellofemoral arthritis should be considered either a contraindication for osteotomy and more amenable to treatment by TKA or combined osteotomy and transfer of tibial tubercle (either an anterior [Maquet] or anteromedial [Fulkerson] transfer) or lateral retinacular release [12–15]. Inflammatory arthritis is by its nature a tri-compartmental disease and therefore osteotomies are not suitable for managing inflammatory arthritis.

Preoperative assessment

Proper patient selection and a detailed clinical assessment are necessary when considering a closing wedge osteotomy for gonarthrosis. This assessment should include a detailed history including age, occupation, activity level, past medical and surgical history, and patient expectations, especially their postoperative activity level expectations. Physical examination should focus on lower extremity range of motion (hip, knee, ankle and foot), deformity, ligamentous stability and leg length discrepancy [5, 8, 16]. Essential radiographs include full-length standing alignment X-rays and standing AP, PA flexion view (Rosenberg view), as well as lateral and merchant views of the knee [5, 15, 17]. The Rosenberg view has a strong predictive value when the chondral wear is prevalent in the posterior part of the tibial plateau [18]. Non-operative management should be pursued initially including activity modification, weight loss, physical therapy, steroid injections, viscosupplementation, and/or an unloader brace. In our clinical opinion, if a patient obtains significant relief with an unloader brace, but is not willing to wear the brace for significant periods of time and feels they have failed non-operative management, strong consideration should be given to osteotomy if no contraindications exist.

Preoperative planning includes the degree of angulation, the wedge size, and location of the osteotomy based on the preoperative imaging templating. Preoperative planning can be performed using traditional templating methods and/or computer assistance. Babais et al. [19] described the use of the OASIS computer software program for lateral closing wedge upper tibial osteotomies and found that knees with a postoperative femorotibial angle of 174–180 degrees, lateral joint line obliquity of less than 4 degrees and a medial plateau force distribution of 40–60% had a decreased risk of failure (Fig. 1). The knees that met these criteria had a 100% survival at five and ten years [19]. Intraoperative computer navigation has also recently been shown to be helpful in assisting with intraoperative correction [20–22]. Saragaglia et al. did demonstrate in a comparative cohort study of computer-assisted versus

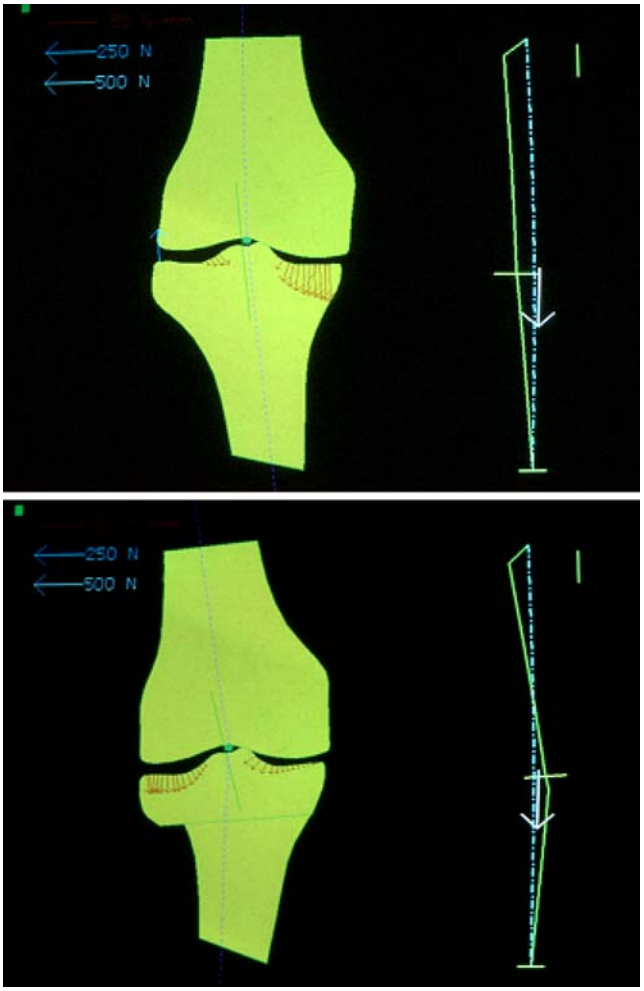

Fig. 1 Preoperative planning with OASIS Software for lateral closing high tibial osteotomy (courtesy of Franklin H. Sim, Mayo Foundation)

conventional high tibial osteotomy a 96% reproducibility in achieving a mechanical axis of 184 degrees ±2 degrees in the computer-navigated group versus 71% in the conventional osteotomy group ($p<0.0015$) [23, 24]. However, no long-term results of computer navigated osteotomies are available to date.

In full-length standing radiographs, a line drawn from the centre of the femoral head to the midpoint of the ankle joint represents the mechanical axis of the leg. A second line is drawn from the centre of the femoral head to a point located at the junction of the medial two-thirds and the lateral one-third of the tibial plateau for varus gonarthrosis. A third line is drawn from the centre of the ankle joint to the previous point. The angle formed by the intersection of the second and third lines determines the degree of correction required for realignment of the mechanical axis (Fig. 2). The goal is to calculate the angular correction necessary to produce 2 to 4 degrees of mechanical or 8 to 10 degrees of anatomical valgus [2, 6, 25].

For valgus gonarthrosis, the same lines are drawn; however, the second line is from the centre of the femoral head to a point located at the 50% coordinate of the tibial plateau [26] (Fig. 3). Clinical experience has shown that overcorrection into varus is absolutely contraindicated if an optimal long-term result is to be gained.

Varus gonarthrosis

The most common procedures for valgus realignment of the proximal tibial articular surface are lateral closing wedge osteotomy, medial opening wedge osteotomy, dome osteotomy or combined osteotomy. Our review focuses on closing wedge osteotomies.

Lateral closing wedge high tibial osteotomy for varus gonarthrosis

The most common indication for lateral closing wedge tibial osteotomies is unicompartmental varus knee gonarthrosis with a well-maintained range of motion of at least 90 degrees of flexion and less than 15 degrees of flexion contracture with varus tibial-femoral malalignment [3, 5, 7, 8, 10, 17, 27–30]. Lateral closing wedge osteotomy is the conventional approach that was used by Coventry et al. [2] and Insall et al. [3] for varus gonarthrosis. Randomised controlled studies comparing lateral closing and medial

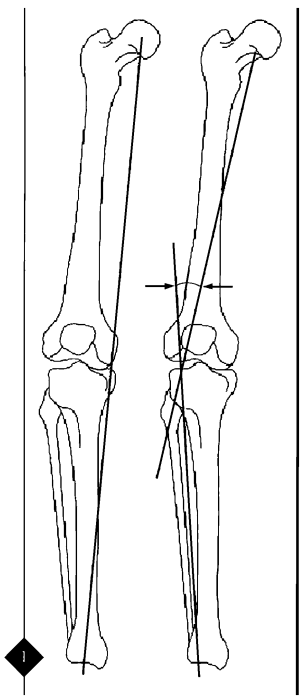

Fig. 2 Preoperative planning for varus gonarthrosis. The correction angle is formed by the line from the centre of the femoral head to the junction of the medial two-thirds and the lateral one-third of the tibial plateau and the line from the centre of the ankle to the medial two-thirds and lateral one-third coordinate (courtesy of the Mayo Foundation)

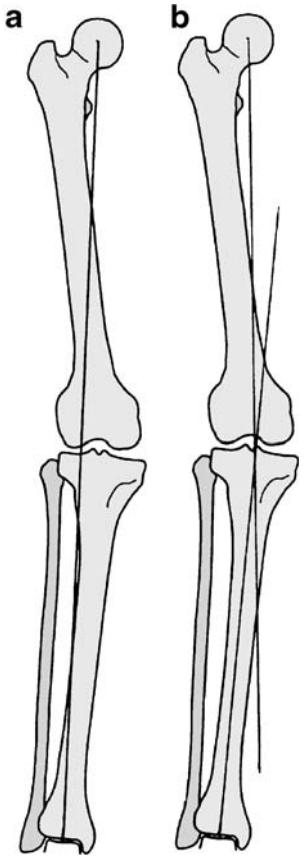

Fig. 3 Preoperative planning for valgus gonarthrosis. The correction angle is formed by the line from the centre of the femoral head to the 50% tibial plateau coordinate and the line from the centre of the ankle to the 50% coordinate [26]

opening wedge osteotomies for varus gonarthrosis have not been performed.

The main advantage of a lateral closing wedge high tibial osteotomy technique is that it results in the apposition of two broad native metaphyseal surfaces and this optimises both stability and healing potential. Lateral closing wedge proximal tibial osteotomy therefore should be considered optimal in comparison to opening medial wedge proximal tibial osteotomy in patients who are at risk for slower healing/nonunion such as patients with a history of nicotine use, diabetics or steroid dependent, patients with patella baja, patients who do not wish to have autograft or allograft, patients on whom the osteotomy is combined with ACL reconstruction, and/or will be non-compliant with weight bearing restriction imposed by medial opening wedge osteotomies. An increased posterior slope is another indication for a closing wedge osteotomy over a medial opening wedge osteotomy because slope can be better controlled using this technique. Closing wedge osteotomy decreases slope, which will correct for the increased anterior tibial translation in ACL-deficient knees and will reduce stresses on an ACL reconstruction, improving anteroposterior stability. Traditionally, lateral closing wedge osteotomies were performed with free-hand cuts and stabilised with either bone staples or cylinder casts [2, 3, 25]; however, a lateral closing wedge osteotomy calibrated guide can increase accuracy [31]. Brouwer et al. [31] actually demonstrated that lateral closing wedge high tibial osteotomy achieved more accurate correction than medial opening wedge high tibial osteotomy of 3.4 degrees versus 1.3 degrees hip-knee-ankle angle; whether or not this will be clinically significant is unknown. In lateral closing wedge high tibial osteotomy, two saw cuts are required and only malalignment in the frontal plane can be corrected.

Medial opening wedge high tibial osteotomies theoretical advantages include restoring anatomy and ligament tension, the possibility of correction in the coronal and sagittal planes, the ability to adjust intraoperatively, the fact that only one bone cut is necessary, and the avoidance of disruption of the proximal tibia-fibular joint. The theoretical disadvantages of medial opening wedge high tibial osteotomies are a slightly higher risk of nonunion, the need for longer period of restricted weight bearing, and the need for either autograft or allograft, although some people do not use graft. Both opening and closing osteotomies can cause patella baja and increased posterior tibial slope.

Combined osteotomy

Typically if greater than 10 degrees of correction is necessary, one should consider either dome osteotomy or combined osteotomy. A combination of opening and closing wedge osteotomies involves removal of a wedge half the width of the tibia from one side and insertion of that wedge into the opposite side, which results in greater angular correction than standard opening or closing wedge osteotomies while preserving leg length. Disadvantages include increased risk of nonunion, avascular necrosis and loss of stability because of discontinuity of the osseous hinge [8, 32].

Technique of closing wedge tibial osteotomy

Many minor modifications of the original Coventry technique of closing wedge osteotomy have occurred since the initial description. Many surgeons now perform a diagnostic arthroscopy to assess the integrity of the lateral compartment and debride the degenerate medial compartment. In some cases the arthroscopic assessment leads to change in surgical intervention and therefore arthroscopy is highly recommended prior to high tibial osteotomy [33]. A straight longitudinal incision on the antero-lateral aspect of the proximal tibia is performed in an effort to respect the possible need for future total knee arthroplasty. Alternatively, a transverse incision from the tibial tubercle to the middle of the fibular head can be used and provides an

excellent scar which does not interfere with further surgery. The extensor muscles are carefully detached from the proximal tibia and fibula and the tibiofibular joint is exposed. All techniques involve either a fibular osteotomy, a release of the proximal tibiofibular joint, or a resection of the proximal medial fibula in order to be able to close the osteotomy and avoid pressure on the peroneal nerve. If in doubt, the peroneal nerve is identified; this however is seldom necessary. Two guide wires are then driven across the proximal tibia under image intensification, the proximal one distal to the joint and at least 2 cm from the joint line and the distal one at a predetermined angle to the proximal one, the tip of the angle being medial. The wedge of bone outlined by the wires is cut with an oscillating saw and removed. One must be careful to remove the hard cortical bone of the posterior aspect of the tibia to avoid a frontal plane deformity when closing the osteotomy. The osteotomy should end medially about 4–6 mm from the outer cortex of the medial tibia. The medial cortical bridge is then weakened with multiple perforations with a drill or a small osteotome and the osteotomy is carefully closed. Fixation methods are variable and include cylinder cast only, external fixation, staple fixation, plate fixation and fixed angle implants. We prefer a Coventry step staple. Brinkman et al. [34] performed a thorough comparison of the various fixation methods. Postoperative care varies from a cylinder cast for five to six weeks to no support at all. Plate fixation or angled stable implants may allow immediate knee mobilisation due to their higher initial stability, and the large contact area after osteotomy closure. More recently, calibrated cutting guides, rigid internal fixation devices and early mobilisation have been used in an effort to improve results and lower complication rates after lateral closing wedge osteotomy [35, 36].

Complications of lateral closing wedge high tibial osteotomy

Complications of high tibial osteotomies include recurrence of varus [3, 8], overcorrection and undercorrection [3], altered patellofemoral kinematics including patellar height changes [37–39], patellofemoral malalignment [40, 41], increased Q-angle and patellar subluxation, fractures, change in tibial inclination, increased joint line obliquity, delayed union and nonunion [3], peroneal nerve and popliteal artery injury [41], shortening of the leg, compartment syndrome, infection and thromboembolism.

Patellar height changes

Historically, lateral closing wedge high tibial osteotomies have been associated with a high incidence of postoperative patella baja [37, 38]. This is undesirable because patellar baja is associated with anterior knee pain and makes later conversion to total knee arthroplasty technically difficult. The patella baja associated with lateral closing wedge high tibial osteotomies is caused by contracture of the patellar ligament associated with conventional cast immobilisation; the incidence reported varies from 7.6 to 8.8% [37, 38]. This can be eliminated by using rigid internal fixation and aggressive postoperative mobilisation [35, 36, 38].

In reality, changes in osseous architecture after lateral closing wedge osteotomy actually increase patellar height, whereas medial opening wedge osteotomy lowers patellar height by raising the tibiofemoral joint line [39]. The 64% incidence of patellar baja without patellar ligament contracture [39] raises concerns regarding adverse impact on patellofemoral mechanics and the ease of subsequent total knee arthroplasty conversion associated with medial opening wedge osteotomy; therefore, a lateral closing wedge high tibial osteotomy is preferred in the patient with preoperative patellar baja over a medial opening wedge osteotomy.

Fracture

Propagation of the osteotomy through the medial cortex during lateral closing wedge high tibial osteotomy is undesirable because the proximal fragment may be destabilised. Preventing this potential problem with careful operative technique can minimise potential for nonunion and malunion. When the complication does occur, fractures must be reduced and stabilised with a medial staple or a medial plate. Another possible fracture complication occurs when there is a crack between the two tibial plateaus into the tibial articular surface; this is a more severe complication because of the potential for articular incongruity. Incidence of intra-articular fracture during closing wedge high tibial osteotomy is reported to be 10 to 20% [42] and is not significantly different from the reported 11% in medial opening wedge high tibial osteotomy. It is recommended that in order to minimise the risk of intra-articular fracture the apex of the osteotomy cut should end within 5 mm of the far cortex, as mentioned above, and leaving the proximal fragment 15 mm thick at a minimum. Gradual closure of the osteotomy permits stress relaxation of the intact far cortex. Also, exaggerating the deformity with an osteotome in the osteotomy site, prior to closing the osteotomy can help avoid fractures through the tibial spine. Kessler et al. demonstrated that medial opening wedge high tibial osteotomy had no advantage over lateral closing wedge high tibial osteotomy in terms of the maximal obtainable correction angle without failure of the far cortex [43]. Addition of drill or small osteotome holes at the apex of the osteotomy can increase the amount of correction obtained before cortical fracture.

Delayed union and nonunion

Nonunion is uncommon after lateral closing wedge high tibial osteotomy because of the excellent healing potential of the two metaphyseal cancellous surfaces that are in a stable, direct apposition configuration. The incidence has been reported to be less than 1% [3, 44]. This is a distinct advantage over medial opening wedge osteotomy which has a rate of delayed union reported to be 6.6% and nonunion of 1.6% [45]. Nonunion and delayed union are more common when the osteotomy is distal rather than proximal to the tibial tubercle (14% versus 3.6%). Factors that have been shown to minimise the risk of nonunion include avoidance of fracture of the medial cortex and retaining the periosteal hinge, broad and flat osteotomy cuts, avoidance of thermal necrosis with the saw blade and secure fixation [7, 46]. Fibular nonunion has been reported in approximately 20% of high tibial osteotomies. Standard management of nonunions includes rigid fixation, often with external fixation in compression and bone grafting.

Peroneal nerve palsy

Peroneal nerve injury is reported to occur between 3.3% and 11.9% and EMG demonstrates nerve damage in up to 27% of patients [47, 48]. Careful lateral dissection and avoidance of retraction when in the vicinity of the peroneal nerve/fibular head is mandatory. Fibular osteotomy >15 cm distal to the fibular head has been associated with a lower rate of peroneal nerve palsy and is recommended by some [49]. We have always done a resection of the medial half of the fibular head and allowed the rest of the fibula to slide upwards when closing the osteotomy; we have not experienced peroneal nerve problems. Application of a tight cast or circumferential dressings, compartment syndrome and excessive angular correction are other possible causes of postoperative peroneal nerve palsy associated with high tibial osteotomy [3, 28, 49].

Compartment syndrome

Although the exact incidence of compartment syndrome after high tibial osteotomy is unknown, elevated anterior compartment pressures are common after high tibial osteotomy. Use of a drain has been shown to decrease anterior compartment pressures [50]. The risk may be increased when an osteotomy is combined with an arthroscopically-assisted ligament reconstruction [51].

Infection

The incidence of deep infection after lateral closing wedge high tibial osteotomy ranges from 0 to 4% [10, 35]. This is lower than the reported incidence in medial opening wedge osteotomies, especially with pin-tract infection in as many as 25 to 50% when an external fixator is used. Septic arthritis or chronic osteomyelitis have been rarely reported [52, 53].

Thromboembolism

It is recommended to consider deep vein thrombosis prophylaxis measures following high tibial osteotomy, similar to those used after total knee arthroplasty due to the reported 41% incidence of deep vein thrombosis after high tibial osteotomy [54] and rare fatal pulmonary embolism [3].

Vascular injury

Vascular injury following high tibial osteotomy is rare, less than 1% [41]. Generally, the osteotomy should be performed with the knee in 90 degrees of flexion, thereby minimising the risk of popliteal artery damage [8].

Results of lateral closing wedge high tibial osteotomy for varus gonarthrosis

Favourable outcomes of lateral closing wedge high tibial osteotomies for varus gonarthrosis have been associated with precise angle of correction, decreased body weight, increased activity level in the younger patient population and lower level of arthritis [2, 55–57]. Babais et al. [19] found that knees with a postoperative femorotibial angle of 174–180 degrees, lateral joint line obliquity of less than 4 degrees and a medial plateau force distribution of 40–60% had a decreased risk of failure. The knees that met these criteria had a 100% survival at five and ten years. This highlights the importance of precise angle of correction and preoperative planning. No study has been able to determine a relationship between outcome and patients' age [57]. Most surgeons agree that in cases of medial gonarthrosis a slight overcorrection of 2 to 5 degrees toward valgus leads to better long-term results [2, 58]. This procedure generally provides good relief of pain and restoration of function in 80–90% of patients at five years and 50–65% at ten years [2, 3, 7, 29, 35, 55, 59, 60]. Many have shown deterioration after ten years [2, 59]. Insall et al. [3] reported good to excellent results in 85–95% after five years and 63% after ten years. They recommended a postoperative tibial-femoral angle of 5 to 14 degrees of valgus as the goal to optimize outcome. Coventry et al. [2] concluded that the relative body weight and angular correction are correlated with survival duration. If at one year after surgery, the valgus angulation was 8 degrees or more or if the patient's

weight was 1.32 times the ideal weight or less, then the probability of survival at five years was 90% or greater and at ten years was 65% or greater. However, if the valgus angulation at one year was less than 8 degrees or if the patient's weight was more than 1.32 times the ideal weight the probability of survival at five years was decreased to 38% and at ten years was decreased to 19% [2] (Fig. 4).

Recently, Flecher et al. [61] found that the most important risk factors predicting revision were age greater than 50 years and a preoperative arthritis Ahlback grade of 3 or more. Survival was 85% at 20 years with revision as the endpoint. Knee function was satisfactory in 77% of patients. Table 1 demonstrates multiple long-term studies which overall tend to demonstrate deterioration after ten years.

Valgus gonarthrosis

The principal procedures for varus realignment of the knee for valgus gonarthrosis are distal femoral medial closing wedge osteotomy, distal femoral lateral opening wedge osteotomy, proximal tibial lateral opening wedge osteotomy and proximal tibial medial closing wedge osteotomy. Our review focuses on closing wedge osteotomies.

The lateral femoral condyle and the lateral tibial plateau have convex surfaces, the congruency is maintained by the integrity of the lateral meniscus. An increased stress due to total or subtotal absence of the lateral meniscus can lead to progressive deterioration of the lateral compartment. Patients who are physiologically young with unicompartmental lateral compartment gonarthrosis should be considered candidates for varus producing osteotomies. If the valgus deformity is greater than 12 degrees, Coventry [10] recommended performing a varus producing osteotomy at the distal femur (Fig. 5). The preoperative range of motion should be at least 90° of flexion. A small degree of extension deficit is tolerable and can be corrected during surgery. Relative contraindications of a varus producing osteotomy include osteonecrosis of the lateral femoral condyle, severe or symptomatic patellofemoral degenerative joint disease, severe gonarthrosis of the medial compartment, history of previous medial meniscectomy, severe tricompartmental gonarthrosis, and a high body mass index. This procedure should not be performed in non-compliant patients or those with a reduced range of motion (flexion <90° or, particularly, extension lag >20°). Absolute contraindications include inflammatory arthritis and extreme valgus deformity associated with subluxation of the tibia.

Fig. 4 A 54-year-old man with medial knee pain and medial gonarthrosis treated by lateral closing wedge high tibial osteotomy with excellent long-term results (courtesy of the Mayo Foundation)

Technique and fixation for medial distal femoral closing wedge osteotomy for valgus gonarthrosis

The technique has not changed significantly from when it was described by McDermott et al. [64]. Distal femoral medial closing wedge osteotomy is performed just proximal to the adductor tubercle and the anterior margin of the femoral articular surface. The majority of surgeons currently perform a diagnostic arthroscopy to assess the integrity of the medial compartment and debride the degenerate lateral compartment. The skin incision is typically a longitudinal medial incision, about 1 cm medial to the anteromedial incision used for primary total knee arthroplasty beginning from the joint line of the knee and extending proximally for 15 cm. The vastus medialis is reflected laterally from the medial intermuscular septum, and care is taken to protect the neurovascular bundle medially in the adductor canal by performing the dissection subperiosteally. A medial arthrotomy of the knee is often used. A medially-based wedge of bone is removed from the proximal femur using guide wires placed parallel to the articular surface. Biplanar fluoroscopy is used. Typically the osteotomy is fixed with a 90-degree dynamic compression blade plate [65]. Fixation with staples is not recommended. Recently, Wang and Hsu [66] described a technique using blade-plate fixation with a derotational screw. Also, van Heerwaarden et al. [67] have described a technique using a TomoFix plate fixator. McDermott et al. [64] state that a flexion contracture of as much as 20 degrees can be corrected by adding extension to the osteotomy. The final correction achieved by the medial distal femoral closing wedge osteotomy should bring the mechanical axis to 50% of the tibial plateau.

Table 1 Lateral closing wedge high tibial osteotomy (HTO) results

Study	Number of HTOs	Follow-up (y)	Results
Coventry et al. [2]	87	3–14 (median, 10)	87% survivorship at 5 years 66% survivorship at 10 years
Insall et al. [3]	95	5–15 (mean, 8.9)	85% good or excellent at 5 years 63% good or excellent at 9 years
Cass and Bryan [44]	86	5 or greater (mean, 9.1)	51% good 31 conversion to TKA
Matthews et al. [42]	40	1–9	50% useful function at 5 years 28% useful function at 9 years 16 conversion to TKA
Sprenger and Doerzbacher [62]	76	Mean 10.8	86% survivorship at 5 years 74% survivorship at 10 years 56% survivorship at 15 years
Billings et al. [35]	64	Average 8.5	85% survivorship at 5 years 53% survivorship at 10 years 21 conversion to TKA
Flecher et al. [61]	301	12–28 (mean, 18)	94.8% survivorship at 5 years 92.8% survivorship at 10 years 89.7% survivorship at 15 years 85.1% survivorship at 20 years 43 knees (14%) required revision
Yasuda et al. [63]	56	6–15	88% satisfactory at 6 years 63% satisfactory at 10 years

Complications of medial distal femoral closing wedge osteotomy for valgus gonarthrosis

Complications of medial closing wedge osteotomy for valgus gonarthrosis are similar to those mentioned with lateral proximal tibial closing wedge osteotomy including overcorrection or undercorrection of the mechanical axis, fixation failure, stiffness, thromboembolism including deep vein thrombosis and pulmonary embolism, compartment syndrome, infection, delayed union or nonunion, and neurovascular injury. If a neurovascular injury occurs at the adductor canal or posteriorly, a vascular repair or reconstruction is necessary using a posteromedial or posterior approach. It is important to use a retractor to protect the posterior neurovascular structures, such as a Hohmann retractor, when performing the osteotomy at the posterior cortex. Drain placement is recommended to attempt to avoid compartment syndrome. It is recommended to consider deep vein thrombosis prophylaxis measures following medial femoral closing wedge osteotomy, similar to those used after total knee arthroplasty. Concerning the soft tissues, it is very important to reinsert the incised medial patellofemoral ligament and the distal insertion of the vastus medialis muscle to avoid patella instability with lateral subluxation [67].

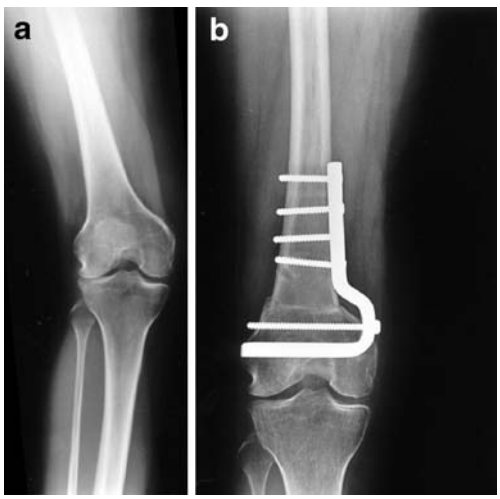

Fig. 5 A 50-year-old woman with lateral gonarthrosis treated by medial femoral closing wedge osteotomy with very satisfactory results (courtesy of the Mayo Foundation)

Results of medial femoral closing wedge osteotomy for valgus gonarthrosis

In comparison to lateral proximal tibial closing wedge osteotomies, there are not many published studies on long-term outcome of medial femoral closing wedge osteotomies for valgus gonarthrosis.

McDermott et al. [64] followed up 24 patients with degenerative arthritis of the lateral compartment treated by a distal femoral varus osteotomy. At an average length of follow-up of four years, 22 of 24 patients had successful results. One osteotomy was revised for failure of fixation and one required conversion to a total knee arthroplasty due to the degree of medial degenerative joint arthritis.

Miniaci et al. [68] reported 86% good or excellent results in a series of 40 supracondylar femoral closing wedge varus osteotomies with a mean follow-up of 5.5 years.

Mathews et al. [69] followed up 21 patients with lateral compartment gonarthrosis and valgus deformity that underwent distal femoral medial closing wedge supracondylar osteotomy with follow up of one to eight years. Fixation methods varied including ten with plaster cast, five with two staples and casting, and six had rigid internal fixation with an AO blade plate. Satisfactory results were achieved in 57% using the clinical rating of the Knee Society. In addition, they had a reportedly high complication rate of 57% including 48% requiring manipulation under anaesthesia due to stiffness, 19% nonunion/delayed union, 10% infection, and 5% fixation failure. Five knees (19%) required conversion to total knee arthroplasty within five years. They concluded that satisfactory results were obtained in patients with grades I to III unicompartmental lateral compartment gonarthrosis, adequate correction of valgus deformity with the anatomical axis within 2 degrees from zero and rigid internal fixation in order to permit postoperative early mobilisation. This study by Mathews et al. highlighted the importance of rigid internal fixation and is therefore the currently recommended fixation.

Wang and Hsu [64] followed 30 knees managed with medial distal femoral closing wedge osteotomy and found that the ten-year survival rate for all patients was 87%. Interestingly, they also found that there was improvement in patellar tracking in seven of eight knees with associated severe patellofemoral arthritis and therefore concluded that the result of osteotomy does not appear to be affected by the presence of severe patellofemoral arthritis.

Proximal tibial medial closing wedge osteotomy for valgus gonarthrosis

When a small correction of 12 degrees or less is required, tibial medial closing wedge osteotomy has been recommended for valgus gonarthrosis. Typically, a joint surface tilt of 10 degrees or less in the coronal plane is well-tolerated [7, 10, 30]. If the correction is greater than 10 degrees, the tibia subluxes laterally and the femur appears to fall off the medial tibial plateau on an AP radiograph [70]. In practice, medial closing wedge tibial osteotomy is not done any more because of this issue of joint line obliquity.

Technique and fixation of proximal tibial medial closing wedge osteotomy for valgus gonarthrosis

After arthroscopy, an antero-medial longitudinal incision is performed and the pes anserinus is partially detached. The superficial layer of the medial collateral ligament is divided and the medial tibial metaphysis exposed. The osteotomy site is confirmed with biplanar fluoroscopy, and the patellar tendon insertion is identified and protected. The osteotomy is performed in a standard fashion using guide wires to prevent entering the epiphysis or joint surface. It is necessary to leave at least 5 mm (ideally 10 mm) of intact lateral tibial cortex as a hinge to ensure stability of the osteotomy. The final correction as in the distal femoral medial closing wedge osteotomy should bring the mechanical axis to 50% of the tibial plateau. Fixation of the osteotomy can be with staples or a four-hole medial plate with two proximal cancellous and two distal cortical screws.

Complications of medial proximal tibial closing wedge osteotomy for valgus gonarthrosis

Complications are again similar to those mentioned previously with lateral proximal tibial closing wedge osteotomies and include overcorrection or undercorrection of the mechanical axis, fixation failure, stiffness, thromboembolism including deep vein thrombosis and pulmonary embolism, compartment syndrome, infection, delayed union or nonunion, and neurovascular injury including peroneal nerve palsy. It is important to again protect the posterior neurovascular structures with a retractor when performing the osteotomy. Drain placement is also recommended to attempt to avoid compartment syndrome. Medial structures are weakened and it is important to perform a layered closure. Medial-lateral laxity can occur, especially if correction is greater than 15 degrees, which results in excessive tibial obliquity.

Results of medial femoral closing wedge osteotomy for valgus gonarthrosis

In comparison with lateral proximal tibial closing wedge osteotomies, there are not many published studies on long-term outcome of medial proximal tibial closing wedge osteotomies for valgus gonarthrosis.

Chambat et al. [30], in a series of 47 patients with medal tibial closing wedge osteotomy followed for a minimum of ten years, found 72% had good or very good results with an improvement in pain in 91%.

Coventry [10] reported on 31 knees treated with a medial proximal tibial closing wedge osteotomy for painful

Fig. 6 A 65-year-old patient with varus gonarthrosis and less than 12 degrees of valgus treated by M.B. Coventry with varus proximal closing wedge tibial osteotomy [10] (courtesy of the Mayo Foundation)

gonarthrosis of the lateral compartment associated with a valgus deformity (Fig. 6). The patients were followed up for two to 17 years, with an average of 9.4 years. Twenty-four knees (77%) had no pain or mild pain at last follow-up, six knees had moderate pain and one knee had severe pain. Six knees required conversion to total knee arthroplasty at an average of 9.8 years after osteotomy.

Postoperative care of closing wedge osteotomies

In general, our recommended postoperative care of all closing wedge osteotomies fixed with a stable internal plate fixation device is immobilisation in a functional brace with range of motion unlimited in the brace. Restricted weight bearing is recommended for four to six weeks, depending on callus formation on follow-up X-rays. As long as the X-rays demonstrate callus formation, at six weeks patients are permitted to begin progressive weight bearing as tolerated. We often use continuous passive motion machines at home for the first two to four weeks to prevent postoperative stiffness. However, classical closing wedge tibial osteotomies done "a la Coventry" were fixed with step staple and protected for five to six weeks with a cylinder cast and partial weight bearing. Recovery of motion and osteotomy healing occurred without exception.

Final considerations

The closing wedge osteotomy preferred in isolated medial compartment varus gonarthrosis is a lateral proximal tibial closing wedge osteotomy. The lateral proximal tibial closing wedge osteotomy is preferred over the medial tibial opening wedge osteotomy in patients with patellar baja, patients who are at higher risk of delayed union or nonunion, patients with increased posterior tibial slope or if the osteotomy is to be combined with anterior cruciate ligament reconstruction.

The closing wedge osteotomy preferred in isolated lateral compartment valgus gonarthrosis is a medial distal femoral closing wedge osteotomy for any degree of correction. Medial proximal tibial closing wedge osteotomy is hardly ever done today.

Closing wedge osteotomies can be used to correct both varus and valgus deformities in the management of isolated medial or lateral compartment gonarthrosis. A number of closing wedge surgical techniques have been described to achieve this goal, and the relative merits of each have been outlined. Critical to the success of the procedure are the selection of the appropriate patient and the attainment of a precise correction without complications. If these goals are met, closing wedge osteotomies can provide long-term relief of pain and restoration of function in patients with localised knee gonarthrosis.

Despite all of the above, our use of osteotomies in the treatment of gonarthrosis has decreased significantly over the last few years. Figure 7 shows the relative frequency per year of distal femoral varus osteotomy, upper valgus tibial osteotomy and unicompartmental total knee arthroplasty at the Mayo clinic over the last 20 years. It is obvious that as our results with unicompartmental arthroplasty have improved, the use of osteotomy has decreased. This is particularly prevalent in patients over the age of 45–50 years. In younger patients osteotomies still remain a very viable alternative.

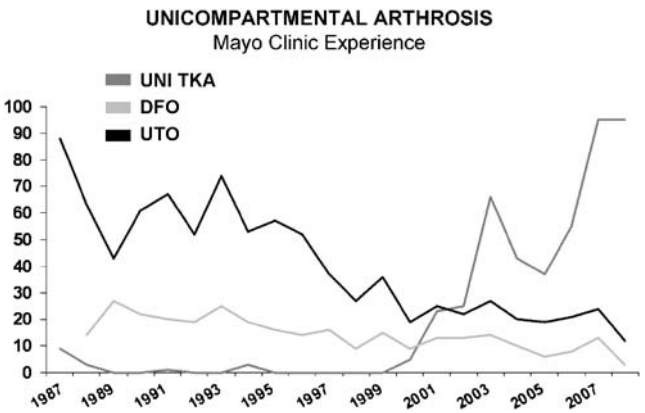

Fig. 7 Relative use of unicompartmental arthroplasty, upper tibial and distal femoral osteotomies at the Mayo clinic over the last 20 years. Note late decrease of osteotomy with corresponding increase of unicompartmental arthroplasty

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