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High Tibial Osteotomy

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1. Introduction

High tibial osteotomy (HTO) has been used for many years to correct angular deformity about the knee, however, its use in the treatment of knee arthritis was not described in the English language literature until 1958 (Jackson 1958). This report presented at the Sheffield Regional Orthopaedic Club detailed Jackson's experience of fourteen osteotomies 'to correct a lateral deformity of the knee accompanied by osteoarthritis'. Six were supracondylar femoral osteotomies and eight were high tibial osteotomies, he concluded that range of motion was better after HTO and overall there was a 'reasonable chance of relieving pain'. HTOs had however, been in use in France for many years before this (Hernigou 1987).

This idea of using a HTO to offload a diseased knee compartment has since been embraced and widely used with multiple techniques employed with varying degrees of success achieved and reported. Typically, high tibial lateral closing wedge osteotomy (HTLCWO) or high tibial medial opening wedge osteotomies (HTMOWO) are used in the management of isolated medial compartment disease with high tibial medial closing wedge osteotomies and distal femoral osteotomies, either lateral opening or medial closing wedge, employed in the setting of lateral compartment disease. Dome osteotomies of the proximal tibia are also occasionally used. As our understanding of knee pathology and biomechanics has changed so to have our indications for HTO usage. Current indications include but are not limited to varus or valgus malalignment with associated symptomatic isolated medial or lateral compartment early degenerative disease respectively, to offload compartments with isolated meniscal or articular cartilage loss, to offload compartments before meniscal or articular cartilage replacement or regeneration surgeries, to attempt to change the natural history and symptomatology of conditions such as spontaneous osteonecrosis of the knee and osteochondritis dissecans, and in the management of knee ligament deficiency.

1.1 Lower limb alignment and axes

Prior to embarking on any surgical intervention to realign or offload a compartment a thorough understanding of the normal mechanical and anatomic axes about the knee is required. The following is a brief description of some of the important axes and angles about the knee. The mechanical axis of a bone is represented by a straight line passing through the centre of the joints above and below that bone, the centre of the hip joint equates to the centre of the femoral head, the centre of the knee to the centre of the tibial spines and the centre of the ankle to the centre of the tibial plafond. The anatomic axis corresponds to the

mid-diaphyseal line, which therefore maybe curved as in the case of the femur in the saggital plane. Usefully, the tibial anatomic and mechanical axes are parallel in the frontal plane, whereas the femoral axes subtend an angle of 7 ± 2 degrees, in the normal population. In order to quantify pre-operative discrepancies and plan correction, the knee joint lines of the femur and tibia must be identified – in the frontal plane these correspond to a straight line drawn between the apices of the convexities of the distal femoral condyles and a straight line between the apices of the concavities of the tibial plateaus respectively. This allows estimation of the lateral distal femoral angle relative to the mechanical and anatomic axes of the femur, 88° ($85-90^\circ$) and 81° ($79-83^\circ$) respectively. The medial proximal tibial angle is 87° ($85-90^\circ$) relative to the tibial anatomic and mechanical axes by virtue of the fact that both are parallel in the frontal plane of the tibia. Overall, this results in lower limb tibio-femoral mechanical alignment in 1.3° of varus and tibio-femoral anatomic alignment in 6.8° of valgus. In the saggital plane the joint line angle of the femur is the straight line that connects the two points of the anterior and posterior meta-diaphyseal junctions, creating a posterior distal femoral angle of 83° ($79-87^\circ$), with the distal femoral anatomic axis in the saggital plane. In the saggital plane the joint line angle of the tibia is drawn along the subchondral bone of the tibial plateau, creating a posterior proximal tibial angle of 81° ($77-84^\circ$), with the tibial anatomic axis (Palley 2002). Using these angles and axes the site of the deformity and the site and degree of correction can be planned pre-operatively.

2. Specific indications for high tibial osteotomy

2.1 Medial compartment arthritis with varus limb malalignment

Isolated medial compartment arthritis with associated varus lower limb malalignment is the most common indication for HTO. The success of this procedure is premised on the fact that seventy per cent of the load generated by the joint reaction force is borne by the medial compartment if the mechanical axis passes through the centre of the knee, whereas this reduces to fifty per cent if the knee is in four degrees of valgus and to forty per cent if the knee is in six degrees of valgus (Kettelkamp et al., 1976). Adequate valgus correction is required to ensure survival of the HTO (Pfahler et al, 2003) this has led most to recommend correction to between two and eight degrees of valgus (Coventry 1993, Hernigou 1987, Jakob 1992), with some advocating correction to between eight and fifteen degrees of anatomic valgus (Aglietti 2003, Koshino 1979, 2004).

Surgical indications include active physiologically young patients with a varus arthritic knee, progressive symptoms unresponsive to six months of conservative treatment, greater than ninety degrees of flexion, less than ten degrees of fixed flexion contracture, intact collateral and cruciate ligaments, no tibio-femoral subluxation and degenerative changes which do not exceed Kellgren-Lawrence grade three. Ideally, the patient should have a body mass index below thirty kg/m^2 , should not smoke, and caution should be employed in the setting of diabetes mellitus or medication usage which may delay healing of the osteotomy. Contraindications include lateral compartment degenerative disease, previous subtotal or total lateral meniscectomy, greater than 3mm of medial tibial bone loss, symptomatic patellofemoral disease, inflammatory arthropathy, patient unwillingness to accept the anticipated post operative appearance of the limb (in valgus) (Wright 2005). Mild to moderate asymptomatic patellofemoral degenerate disease is typically not a contraindication to HTO.

The ideal patient should have a normal lateral compartment before transferring load to it in performing the osteotomy, however, while consensus exists regarding the need to assess the lateral compartment, consensus does not exist regarding the means by which the compartment is assessed pre or intra-operatively. A thorough history and physical examination should focus on excluding pain generators within the lateral compartment. Radiological evaluation should include weight bearing plain radiographs. A schuss view taken PA with the patient weight-bearing with the knees at thirty degrees of flexion should be considered pre-operatively as it has been shown to be more sensitive than standard AP weight bearing radiographs in identifying patients with loss of joint space in the lateral compartment in particular (Ritchie 2004). MRI scanning is also utilized to assess the integrity of the lateral compartment, specifically the lateral meniscus and as technologies improve, the quality of the articular cartilage. Some routinely perform arthroscopy as part of the surgery to assess the lateral compartment (Song 2010). Intra-operative arthroscopy facilitates assessment and management of medial meniscal tears, which are common in this patient population, as well as aiding in accurate assessment of a tibial plateau fracture, should one occur.

When a patient is deemed suitable for a HTO the next question is what type of osteotomy to use. As outlined above, a dome osteotomy, although very effective in correcting deformity and shifting the mechanical axis, is less commonly used now, hence this chapter will concentrate on the pros and cons of medial opening and lateral closing wedge osteotomies. Often the decision is based on surgeon preference for one type of osteotomy over the other; however, individual patient factors should also be considered during the pre-operative plan. A patient with a limb length discrepancy resulting in the affected lower limb being longer pre-operatively may be more appropriately considered for a HTLCWO rather than a HTMOWO which will further lengthen the leg, with the former shown to shorten the leg by 2.7 +/- 4mm and the latter shown to lengthen the leg by 5.5 +/- 4.4mm (Magnusson 2011). Similarly, the patella height on the pre-operative radiograph should also be assessed and the patient with patella baja considered for a lateral closing wedge and early post operative mobilization as opposed to a medial opening wedge osteotomy which has been shown to reduce patellar height (Wright 2001). Careful analysis of the pre-operative radiographs is a critical in determining the degree of planned correction. Using full length standing radiographs, the mechanical axis is outlined by drawing a line from the centre of the femoral head to the centre of the ankle joint. Once it has been determined that the varus deformity is on the tibial side, the planned angular correction is determined by drawing a line from the centre of the femoral head to a point at sixty two per cent of the total width of the tibial plateau measured from medial to lateral, known as the Fujisawa point (Fujisawa 1979). A second line is then drawn from the centre of the ankle joint to this point - the angle subtended by these two lines is the angular correction required to bring the mechanical axis to this Fujisawa point in the lateral compartment thereby offloading the medial compartment. Using medial opening wedge techniques the degree of correction can be adjusted intra-operatively as outlined below however, using closing wedge techniques the angular correction must be planned and converted to millimeters at the site of the closing wedge osteotomy on pre-operative imaging measured at a set distance from the joint line so as to ensure the correct size wedge is osteotomised for the desired correction. If using this technique when performing closing wedge surgery the soft tissue component of the deformity must be taken into account by subtracting one degree for every millimeter of

additional lateral compartment opening in the standing view of the varus knee, from the planned wedge, so as not to over-correct resulting in excessive valgus once the patient weight bears (Noyes 2000). Opinions differ as to the exact amount of correction required or likely to be cosmetically acceptable to the individual patient, hence the actual point chosen is typically somewhere between the Fujisawa point and the lateral border of the lateral tibial spine.

2.1.1 Surgical technique – High tibial medial opening wedge osteotomy

The patient is positioned supine on a radiolucent operating table allowing intra-operative fluoroscopic visualization from the centre of the femoral head to the centre of the ankle joint. The chosen anesthetic and antibiotics are administered. A thigh tourniquet is applied to the operative limb and standard prep and drape is performed. A vertical incision, eight centimeters in length, is made over the centre of the medial tibial plateau. The sartorial fascia is incised just proximal to and inline with the gracilis tendon. The superficial medial collateral ligament is identified. A 1.8mm threaded k-wire is passed obliquely under image guidance from the metaphyseal flare of the proximal medial tibia towards the head of the fibula – ensuring it exits fifteen to twenty millimeters below the lateral tibial plateau. A second threaded K-wire is then passed obliquely, from a point one to two centimeters postero-inferior to the first k-wire, ensuring it is parallel to the first k-wire in the coronal plane, and that a line drawn between these k-wires is parallel to the slope of the proximal tibia in the sagittal plane. Using intra-operative AP imaging this can be verified by measuring the angle of the posterior slope of the tibia on the pre-op radiograph, then flexing the knee to this amount should cause superimposition of one wire over the other on AP imaging if the planned posterior slope has been replicated. The medial collateral ligament is then sharply divided along the planned osteotomy site, just distal to and paralleling these two wires. Care must be taken to ensure the MCL is completely divided especially posteriorly to ensure it does not act as a tether preventing opening of the osteotomy posteriorly thereby potentially increasing the posterior tibial slope.

Then knee is then flexed and a Cobb or broad tissue elevator is then passed subperiosteally along the posterior tibia in the direction of the planned osteotomy. A sagittal saw is then passed under image guidance from medial to within five to ten millimeters of the lateral cortex staying in direct contact with the two k-wires so as not to deviate from the planned osteotomy path. The posterior cortex is osteotomised in the same plane, guided by the k-wires and the broad tissue elevator being key to protecting the posterior neurovascular structures throughout the procedure. A fifteen degree oblique osteotomy posterior to the tibial tuberosity in an anterior proximal to posterior distal direction is then performed using the sagittal saw taking care to protect the patellar tendon throughout. If however, the medial tibial opening wedge osteotomy is utilized in a patient with patella baja or in whom a significant correction is anticipated, the tibial tuberosity is osteotomised obliquely from the level of the osteotomy to distal, maintaining the tuberosity in continuity with the proximal fragment thereby not altering the spatial relationship between the patella and the proximal tibia (Gaasbeek 2004).

At all times when using the sagittal saw, saline lavage is employed to prevent local soft tissue or bone necrosis. The osteotomy of the anteromedial and anterolateral cortices of the proximal tibia are then completed using an osteotome. A 3.2mm drill is then passed from

medial to lateral to the intact lateral cortex which is then drilled in three different sites from anterior to posterior again in line with the k-wires. This serves to weaken the lateral hinge and allow it open by plastic deformation rather than fracture during the remainder of the procedure. The osteotomy is then slowly opened using stacked osteotomes slowly inserted under image guidance from medial to lateral to within five to ten millimeters of the lateral cortex until the desired degree of opening, as per pre-operative planning, is obtained. The first two broad osteotomes are inserted with additional osteotomes thereafter inserted between these two. A laminar spreader is then inserted as posterior as possible to hold the osteotomy in this position as the osteotomes are removed. The osteotomy should be opened twice as much posteriorly as it anteriorly to ensure alteration of the posterior slope does not occur. The adequacy of the correction is then assessed using fluoroscopy, by positioning the proximal end of the diathermy cable over the centre of the femoral head and the distal end of the cable under tension over the centre of the ankle, where this passes through the extended knee under image intensification corresponds to the new mechanical axis, which can easily be adjusted using the laminar spreaders so that it crosses the desired point between the lateral border of the lateral tibial spine and the Fujisawa point.

At this point the osteotomy can be fixed by a variety of means, the one described here uses a proximal tibial locking compression plate, TomoFix® (Synthes GmbH; Solothurn, Switzerland) which is applied to the proximal tibia, with a two millimeter spacer in the most distal of the four proximal locking screw holes and another in the most distal of the four distal screw holes. These spacers prevent soft tissue necrosis under the plate, particularly of the pes anserinus tendons and periosteum adjacent to the osteotomy. A 2.0mm k-wire is passed through the middle of the proximal three locking drill guide sleeves, parallel to the joint to hold the plate in position while the remaining anterior and posterior proximal locking screws are inserted. This k-wire is then removed and replaced by a screw. The most proximal of the four screw holes distal to the osteotomy site is then drilled to accommodate a cortical screw to reduce the tibial shaft to the plate. The middle two distal screw holes are then filled with unicortical locking screws. The two spacers and then the cortical screw are removed at this point and replaced by locking screws.

A variety of graft options exist to fill the osteotomy site including autograft, allograft, synthetic bone graft substitutes and synthetic bone scaffolds, studies exist to support each. Using the above technique increasingly no bone graft is used to fill the osteotomy with satisfactory results reported to date (Staubli 2010). This avoids the morbidity associated with autograft harvesting sites, allograft infection risks and the difficulties in achieving bony union associated with the use of synthetic graft materials, but does require that the plate remain in situ for eighteen months post-operatively.

The skin and subcutaneous tissue are closed over a non-suction drain using interrupted sutures. A standard dressing applied. Range of motion is commenced on day one following removal of the drain. Partial weight bearing of fifteen kilograms is allowed until the wound is fully healed, generally between ten and fourteen days, at which point weight bearing as tolerated is permitted, with the patient mobilizing without crutches from six weeks post-op. Although opinions vary, this protocol may be applicable to medial tibial opening wedge osteotomies using the above described fixation technique, however, the post-op protocol should be tailored to the stability of the fixation technique used so as to prevent loss of fixation.

2.1.2 Surgical technique – High tibial lateral closing wedge osteotomy

The lateral tibial closing wedge osteotomy was originally described and popularized by Coventry (Coventry 1965), since then the operation has undergone a number of technical variations especially in relation to dealing with the proximal tibio-fibular joint and fibular osteotomy, in an effort to avoid complications relating to the peroneal nerve in particular.

The patient is position supine on the radiolucent operating table allowing intra-operative fluoroscopic visualization from the centre of the femoral head to the centre of the ankle joint. The chosen anesthetic and antibiotics are administered. A thigh tourniquet is applied to the operative limb and standard prep and drape is performed. An arthroscopic evaluation of the joint may be performed at this point.

A curved oblique incision is utilized extending from the tip of the fibula to the tibial tuberosity anteriorly before descending approximately three centimeters long the lateral border of the tibial tuberosity. The tibialis anterior insertion is released as a z-plasty to facilitate later repair, the tibialis anterior and long toe extensor musculature is taken down using a large periosteal elevator to expose the lateral proximal tibial metaphysis. The proximal tibio-fibular joint is then opened to allow mobilization of the proximal fibula. A 1.8mm threaded k-wire is passed under image guidance from lateral to medial twenty millimeters below and parallel to the joint line, with its starting point as far posterior as possible. A second k-wire is then passed two centimeters anterior and parallel to the first. This k-wire should be superimposed on the first on imaging with the knee in extension. To mark the distal osteotomy a k-wire is passed obliquely from medial to lateral at the desired distance from the proximal osteotomy site as per pre-operative planning again with its starting point as posterior as possible, to converge with the proximal osteotomy wires at the medial cortex. A second k-wire is then passed from a starting point one to two centimeters anterior to and parallel to the first, again superimposition is checked on fluoroscopy with the knee in extension. A Cobb or large periosteal elevator is passed posterior to the proximal tibia to protect the posterior structures as the osteotomy is performed. Similarly, a right angle retractor is placed posterior to the patellar tendon to protect it while the osteotomy is performed. The proximal osteotomy is performed first using a sagittal saw passed distal to but in direct contact with the k-wires at all times from lateral to medial leaving the posterior tibial cortex intact. Image guidance is used to ensure the sagittal saw is taken to within five to ten millimeters only of the medial cortex. The distal osteotomy is then performed with the sagittal blade resting on the proximal surface of the distal osteotomy marker k-wires, again converging on the proximal k-wires but staying five to ten millimeters from the medial cortex. The distal osteotomy includes the posterior cortex along its length. The wedge is then removed with osteotomes; a curette is used to ensure cancellous bone is removed from the posterior cortex which has been left intact on the proximal fragment to add stability to the construct at completion (Coventry 1965). A 3.2mm drill is then passed from lateral to medial three times through different points on the medial cortex from posterior to anterior to weaken this medial hinge and allow it deform without fracturing. A valgus load is then slowly applied using a large reduction clamp on the lateral side to close the osteotomy. Using the diathermy cable as outlined in the medial opening wedge technique discussion above the new mechanical axis is assessed, if it is deemed satisfactory the osteotomy is held reduced with two staples on the lateral side. The capsule of the proximal tibio-fibular joint and anterior compartment musculature are then repaired using interrupted sutures. The

skin is closed. Standard dressings are applied. Epidural anesthesia should be avoided post-operatively as it may mask the development of a compartment syndrome which should be carefully watched for. Range of motion rehab and partial weight bearing are commenced day one post operatively due to the inherent stability of the construct. Early range of motion rehab is crucial to prevent patella baja (Billings 2000). Earlier papers have recommended the use of long leg casting for six weeks and partial weight bearing to maintain alignment when staples are employed for fixation if the boney contact within the osteotomy site is less than 50% (Harrison 1987).

2.2 Lateral compartment arthritis with valgus malalignment

A much less common indication for osteotomy relates to the valgus knee with lateral compartment arthritis. Similar indications and contra-indications as in the setting of the varus knee as outlined above are utilized. Clinical exam should include careful assessment of other joints to outrule an as yet undiagnosed rheumatologic condition which may be driving the valgus deformity and indicative of tri-compartmental disease within the joint. Similarly, it is important to outrule any hip adduction contracture as this will create a valgus moment about the knee and likely lead to recurrence of the deformity over time.

The use of a HTO to correct valgus malalignment or to offload the lateral compartment requires careful consideration particularly with regard to the anatomy of the involved knee. Where a valgus knee is boney in origin the problem typically lies on the femoral side, most often due to dysplasia of the lateral femoral condyle. The resultant knee valgus is apparent clinically in both flexion and extension. This presents the surgeon with the difficult decision as to which side of the knee joint to perform the osteotomy on. A HTO in this setting, particularly if the proximal tibia is not contributing to the deformity will correct the deformity in both flexion and extension but will, by necessity, create joint line obliquity. A distal femoral osteotomy, on the other hand, while not changing the obliquity of the joint line will usually only correct the deformity in the coronal plane, resulting in persistent valgus in flexion.

2.2.1 Surgical technique – High tibial medial closing wedge osteotomy

Pre-operative planning as described is utilized to determine the size of the wedge required at the level of the osteotomy to achieve the desired correction, of 0-2 degrees of mechanical tibio-femoral varus. The osteotomy is performed just proximal to the tibial tubercle. As in section 2.1.1 above, the same technique is utilized to expose the medial proximal tibia. The hamstring tendons are identified and retracted, the superficial MCL is identified and its fibres, which are often lax in this setting, are elevated off bone and retracted posteriorly at the level of the planned osteotomy. Two 1.8 mm threaded k-wires are passed, as guidewires, from medial to lateral parallel to the joint line and each other, in both the coronal and saggital planes, to exit the lateral tibia just proximal to the proximal tibio-fibular joint. The proximal tibial fragment should measure at least 2 cms at its thinnest point. Fluoroscopy is used to ensure correct guidewire positioning as per pre-operative planning. The knee is then flexed and a wide periosteal elevator is passed along the posterior cortex of the proximal tibia along the line of the planned osteotomy and its position again checked under fluoroscopy. The patellar tendon is retracted. A saggital saw is used to osteotomise the proximal tibia just distal to, but staying in contact with the already positioned guidewires. The osteotomy should include the anterior and posterior cortices and should extend to but

not through the lateral cortex. The thickness of the planned resection wedge is measured on the medial cortex and two further 1.8 mm threaded guidewires are then passed from medial to lateral to converge with the two proximal guidewires just medial to the lateral cortex. When measuring the medial wedge thickness allowance must be made for the thickness of the saw blade, being utilized, to reduce the risk of over-correction. These two guidewires should be parallel to the proximal two guidewires in the sagittal plane so as not to change the posterior tibial slope. The wide elevator again is used to protect the posterior structures before the osteotomy is performed using the sagittal saw just distal to but in contact with these two distal guidewires, again the osteotomy extends to but not through the lateral cortex. The resection wedge is removed and a 3.2 mm drill is used to perforate and weaken the lateral cortex as required to allow gentle varus directed force close the osteotomy site. The diathermy cable under tension is passed from the centre of the femoral head to the centre of the ankle joint and fluoroscopy used to ensure the new mechanical axis passes through the centre of the knee. The osteotomy is then held reduced with two bones staples. The superficial MCL is assessed and a decision made as to whether to double breast suture it over itself or whether to excise a redundant portion of its fibres and re-oppose its edges at an appropriate tension. The tissues are closed over one deep drain. Early partial weight bearing is allowed in this setting due the stable nature of this construct and broad metaphyseal surfaces for bony healing.

2.2.2 Surgical technique – Distal femoral medial closing wedge osteotomy

When the required valgus deformity correction exceeds 12 degrees, that correction is best performed through a distal femoral medial closing wedge osteotomy (Figure 1); in order to avoid excessive joint line obliquity as would likely occur with a correction of this magnitude on the tibial side (Coventry 1987). As outlined above pre-operative planning is again of paramount importance. First the angular magnitude of the required correction is determined to bring the mechanical axis of the limb through the centre of the knee. The osteotomy site is then identified radiologically such that it will be as distal as possible without compromising the patellofemoral joint. The width of the osteotomy at this site in millimeters is then determined.

The patient is positioned supine on a radiolucent operating table allowing intra-operative fluoroscopic visualization from the centre of the femoral head to the centre of the ankle joint. The chosen anesthetic and antibiotics are administered. A thigh tourniquet is applied to the operative limb and standard prep and drape is performed. An arthroscopy is performed in particular to assess the medial compartment for any degenerate changes and to treat meniscal or chondral pathology in the lateral compartment. A vertical paramedian incision, approximately 2 cms medial to a midline incision is utilized extending proximally for 15 cms from the level of the joint line. A subvastus approach thereafter is used to elevate the vastus medialis obliquus (VMO) off the medial intermuscular septum to facilitate exposure of the medial distal femur. The medial superior geniculate vessels are identified and ligated as required. A guidewire is passed from anteromedial to posterolateral, parallel to and 2 cms proximal to the joint line under image guidance. This serves as a marker for the blade plate insertion site, which should be approximately 2 cms distal to the proposed osteotomy site, a second guidewire is then passed 1.5 cms anterior to the first such that the wires are parallel to the joint line in the coronal plane and perpendicular to the long axis of the femur in the sagittal plane, so that when the blade plate is inserted it will lie on the femoral shaft.

A 4.5 mm drill is used to perforate the medial femoral cortex between these 2 guidewires, the blade plate chisel with the plate holder attached is inserted parallel to the guidewires under image guidance again ensuring that the plate holder remains parallel with the long axis of the femur. The chisel is removed, to mark the proposed distal limb of the osteotomy site, as defined on the preoperative plan, two threaded 1.8mm guidewires are passed from medial to lateral, approximately 2 cms proximal to and parallel to the first two guidewires, which can then be removed. Two guidewires are used at all times to maintain visuospatial awareness of the correction in the saggital plane so as to avoid building flexion or extension into the correction. The patellofemoral joint should be assessed to ensure it will not be breached by the distal osteotomy. A broad periosteal elevator is passed along the posterior cortex of the femur with the knee in flexion to protect the neurovascular structures and a homann retractor is placed anteriorly to protect the quadriceps tendon. A broad saggital saw is used to perform the distal limb of the osteotomy just proximal to but in direct contact with the guidewires. The osteotomy extends to but not through the lateral cortex.

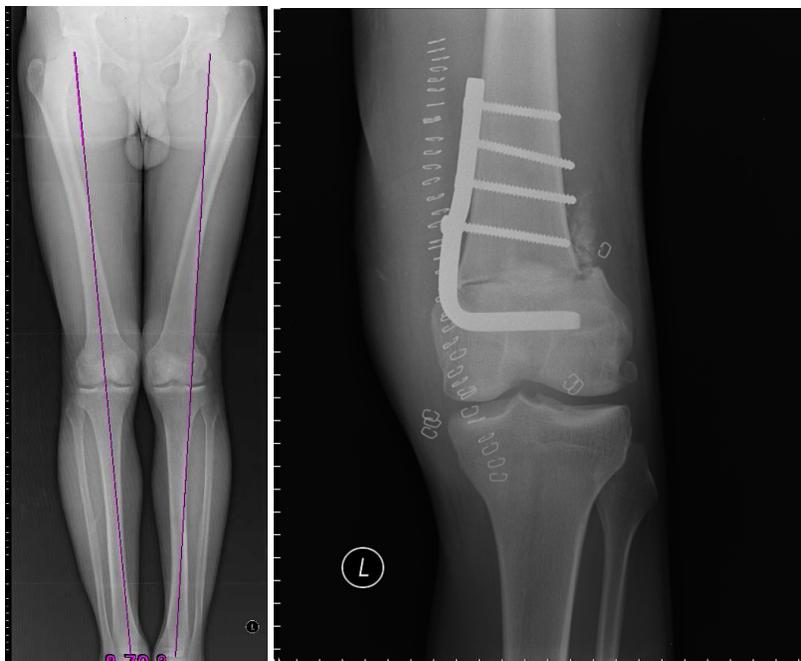


Fig. 1. Pre-operative 3 foot standing film showing significant left knee valgus with the mechanical axis passing through the centre of the lateral compartment, with adjacent post-operative film following medial distal femoral closing wedge osteotomy with correction of the deformity.

The planned width of the resection wedge is measured on the medial cortex and two 1.8 mm threaded guidewires passed from medial to lateral such that they converge just medial to the distal osteotomy guidewires in the coronal plane but are parallel to them in the saggital plane. The broad periosteal elevator and homann retractor are replaced and the proximal limb of the osteotomy is completed in similar fashion staying just distal to but in direct contact with the proximal osteotomy limb guidewires. The wedge of bone is removed and the intact lateral cortex weakened using a 3.2 mm drill bit to facilitate closure of the osteotomy without fracture of the lateral hinge. Fluoroscopy is used to check that the new mechanical axis passes through the centre of the knee. A five hole 95 degree plate with a 50-60mm blade is then bent to 90 degrees so as to allow complete osteotomy reduction and

compression along a line perpendicular to the femoral shaft (Wang 2005). The blade is impacted into the distal femur along the pre-chiseled path. The bone of the medial distal femur just proximal to the blade is compressed by the plate if soft or impacted using a punch to allow seating of the plate within the cortex of the distal femur until the plate lies on the femoral shaft, without requiring medialisation of the shaft which would compromise the correction and disrupt the continuity of the lateral cortex. This is also the reason for choosing a shorter blade and negates the need for the use of offset blade plates which are bulky, can compromise postoperative range of motion and often require removal due to pain. Consideration at this stage, based on bone and osteotomy fixation quality, can be given to using a derotation screw either through the plate or outside the plate to cross the osteotomy and aid in controlling rotation of the distal fragment and facilitate earlier range of motion rehabilitation (Wang 2005). The wound is closed in layers using interrupted sutures. Toe touch weight bearing only is permitted for the first six weeks, thereafter weight bearing is gradually re-introduced.

3. High tibial osteotomy for ligamentous insufficiency

Prior to embarking on ligamentous or joint preserving surgeries about the knee careful attention must be paid to the alignment of the limb as well as the actual joint involved – namely the knee in this chapter. If malalignment has contributed to meniscal, cartilage or ligamentous injury and that malalignment is not corrected prior to or at the time of a planned reconstructive surgery – that reconstruction will be subject to the same stresses which resulted in the failure of the native tissues in the first place resulting in higher failure rates in the reconstructed tissues also. The importance of the history and physical examination in this setting cannot be overplayed. A precise history of pre-injury function, pain, range of motion, previous injuries or surgeries are crucial to elucidate, prior to enquiring as to the exact injury mechanism leading to the current consultation. Relatively innocuous injury, previous failed surgery for the same condition or bilaterality should alert the physician to the possibility of fundamental structural malalignment which may contribute to early failure of a repair or reconstruction.

The clinical exam is critical and must start with assessing limb alignment during gait to look for dynamic instability in the knee joint under load, before looking at alignment in standing and the status of individual ligaments. While walking, a varus thrust or knee hyperextension gait must be carefully sought out, as isolated ligamentous reconstructions of the anterior or posterior cruciate ligaments respectively in these settings will likely result in poor surgical outcomes. Standing alignment and old surgical scars should be noted prior to a thorough examination of the individual ligaments of the knee looking for increased lateral opening at 30° of knee flexion when a varus directed force is applied, increased external or posterolateral rotation at 30° and 90° of flexion, increased subluxation on the reverse pivot-shift test, increased anterior translation on the lachman and anterior drawer tests, and increased posterior translation on the posterior drawer test for a posterior cruciate ligament (PCL)-deficient knee all compared with the normal contralateral knee.

Radiological assessment involves careful analysis of the current mechanical axes on the three foot standing films, as well as joint space narrowing on the medial side and opening on the lateral side. The lateral x-ray is used to assess the patellar height and the posterior tibial slope, the angle subtended by two lines, one drawn parallel to the long axis of the tibial diaphysis

and the other from the anterior proximal tibia to the posterior proximal tibia, to give a normal value of between 7 and 10 degrees. The importance of the posterior tibial slope has been highlighted by numerous investigators who have shown that with increasing posterior tibial slope comes increased anterior translation of the tibia on the femur (Giffin 2004), with some advocating reduction of the slope if it is greater than 10 degrees in the ACL deficient knee (Dejour 1994). The common finding of posteromedial wear in the ACL deficient knee and cadaveric studies showing increased pressure transmitted to the osteotomised knee with increased posterior slope further highlight the importance of this point (Rodner 2006). The opposite applies to the PCL deficient knee in which increasing the posterior tibial slope may indeed be beneficial by reducing the posterior sag in flexion.

3.1 Anterior cruciate ligament deficiency and the varus knee

One of the commonest elective orthopaedic operations performed is reconstruction of the torn anterior cruciate ligament (ACL) in the knee. Much modern debate and literature centers on graft selection, tunnel placement and graft fixation methods. However, perhaps more important than any of these debates is patient selection and pre-operative assessment, so as to identify that patient who is predisposed to failure of an isolated reconstruction of the ACL. A patient who gives a history of previous ACL reconstruction on the other or same side, who has had a previous medial meniscectomy or longstanding instability warrants careful assessment for varus malalignment. Noyes has written extensively on the subject, breaking down the varus ACL deficient knee into three categories, namely, primary, double and triple varus. Primary varus is used to define the patient with osseous tibio-femoral varus alignment, which may or may not be worsened by medial meniscal or medial compartment articular cartilage loss. Where varus in this setting has resulting in attenuation of the lateral soft tissue restraints with lateral compartment widening the term double varus is used and finally triple varus is encountered in the knee that due to chronic or acute injury adopts a varus recurvatum posture (Noyes 2000).

When double or triple varus is encountered it is recommended that ACL reconstruction be performed in conjunction with or after high tibial osteotomy, with posterolateral soft tissue reconstruction added in the setting of triple varus. The type of HTO utilized is usually either a HTMOWO or a HTLCWO, with every effort made to avoid increasing the posterior tibial slope, in order to avoid increasing stresses transmitted to the ACL graft. Important subtleties in lateral closing wedge surgery in this setting relate to ensuring the new mechanical axis passes through the Fujisawa point and avoidance of disruption of the proximal tibio-fibular joint so as not to further defunction the lateral ligamentous restraints. Osteotomy of the fibula should be performed at the level of the neck with removal of a wedge of bone to allow compression as the tibial osteotomy is closed (Noyes 2000). A HTMOWO should be considered where patella alta pre-exists, where concomitant MCL surgery is required, and where limb length discrepancy with the operative limb being shorter is encountered. Similarly, if the HTO and ACL reconstruction are being performed simultaneously - both can be performed with relative ease through the one anteromedial incision (Amendola 2004) (Figure 2). This single stage combined technique has demonstrated excellent medium term survival and return to function. In a French retrospective study of 30 ACL deficient knees with early medial compartment arthritic changes, in 29 patients of mean age 30 years who underwent single stage ACL reconstruction and HTO (25 closing wedge and 5 opening wedge), at mean follow up of 12

years, 47% were still involved in intense sporting activity namely skiing, tennis and soccer, while a further 36% described their involvement in sporting activity as moderate. Radiologically only 17% of this cohort had progressed one grade at final follow-up (Bonin 2004).



Fig. 2. Mechanical axis pre and post combined HTMOWO and ACL reconstruction.

3.1.1 Surgical technique – Single stage HTO and ACL reconstruction

A careful stepwise approach however, is required to avoid complications. The steps involved include, arthroscopy to assess the articular surfaces, debridement or repair of meniscal injuries, notch preparation, anteromedial incision over the proximal tibia, hamstring harvest and preparation, passage of two 1.8 mm threaded guide wires along the path of the medial opening wedge tibial osteotomy, paying careful attention to the sagittal alignment of these wires so as not to increase the posterior tibial slope through the osteotomy, if anything the slope of the line joining these wires in the sagittal plane should be less than the current posterior tibial slope of the patient. Next the femoral tunnel is drilled through an anteromedial tunnel followed by tibial tunnel drilling proximal to the osteotomy site guide wires with consideration given to ultimate proximal tibial locking plate and screw placement, as well as the position of the tibial tubercle osteotomy step cut. The medial opening wedge osteotomy is then performed using standard techniques as outlined above ensuring that the osteotomy is opened using laminar spreaders, twice as much posteriorly as it is anteriorly, so as not to increase the tibial slope (Noyes 2005). The final drill used for the tibial tunnel is re-introduced by hand into the tibial tunnel and left in situ while the proximal tibial locking plate is applied across the osteotomy and provisionally held with k-wires through the proximal locking holes to ensure the ACL tibial tunnel will not be compromised by the proximal locking screws from the plate. The k-wires in the locking plate are replaced by screws to fully stabilize the osteotomy. The ACL graft is then

passed and fixed on the femoral side, cycled and fixed on the tibial side using dual fixation, however, the proximal tibial locking plate should not be used as a means of secondary fixation for the tibial graft as it occasionally requires removal at a later date. The arthroscope is re-inserted into the knee – the lateral tibial plateau is examined for evidence of iatrogenic fracture and the tension within the ACL graft is checked, the knee is thoroughly washed out and the wounds closed using interrupted sutures. Rehabilitation should commence the following day with patellar mobilization, early knee range of motion; isometric quadriceps strengthening and toe touch weight bearing for six weeks.

3.2 Chronic posterolateral instability and the varus knee

With improved understanding of the anatomy and biomechanics of the structures of the posterolateral corner of the knee has come a trend towards early repair or reconstruction of these structures with a view to returning the patient to pre-injury function as soon as possible. Nonetheless, many of these patients are not seen 'early', within 2-3 weeks of injury, by a surgeon with a specialist interest in treating these injuries, and therefore are seen or present on a delayed basis.

When a patient with chronic posterolateral instability of the knee is seen a careful assessment of the alignment of that knee is once again warranted. The fact that two convex surfaces, the lateral femoral condyle and lateral tibial plateau, articulate within a compartment bounded by a mobile lateral meniscus adds to the instability of the compartment placing increased stresses on the posterolateral structures for stability. Varus malalignment will place continued stress across any planned reconstruction and likely ultimately lead to failure of that reconstruction. Biomechanical studies have shown reductions in lateral compartment opening when a varus moment is applied and tibial external rotation when an external rotation torque force is applied to a posterolateral corner deficient cadaveric knee following HTMOWO. It should be noted that, unlike in the technique described previously in this chapter, the superficial MCL was left intact at the level of the osteotomy in this study and was thought to add to the stability of the knee through tightening of the posteromedial structures through its attachments to the deep MCL and posterior oblique ligaments. However, the effect of this statistically significant increase in tension in the superficial MCL, when both varus moments and external rotation torques were applied, on the articular cartilage of the medial compartment is, as yet, unknown (LaPrade 2008). These findings of increased stability in the posterolateral corner deficient cadaveric knee following HTMOWO have been backed up by clinical studies showing that 38% of patients with combined varus malalignment and posterolateral corner insufficiency treated initially with HTMOWO did not require subsequent reconstruction of their concomitant posterolateral corner insufficiency. This study of 21 patients with a mean follow up of 37 months concluded that those patients with isolated chronic posterolateral corner insufficiency, low energy injury mechanisms and higher pre-operative knee function scores were least likely to require secondary posterolateral corner reconstruction following HTMOWO to correct varus malalignment (Arthur 2007).

4. Complications of high tibial osteotomy

General complications of any surgical intervention can be broken down into acute intra-operative, acute post-operative (within hours), early post-operative (within days to weeks)

and delayed post-operative (within months to years). Broadly speaking, in this setting, acute intra-operative complications include direct neurovascular injury when performing the tibial or fibular osteotomies, intra-articular proximal tibial fracture, fracture of the medial or lateral tibial cortical hinge, tibial tubercle fracture with disruption of the patellar tendon and extensor mechanism, failure to adequately correct the deformity, intra-articular placement of fixation screws or staples.

Acutely post-operatively neurovascular complications predominate with compartment syndrome, bleeding from the osteotomy site or from direct vascular injury occasionally encountered, similarly neural palsies typically declare themselves during this time frame. Infection, thrombo-embolic events, stiffness and pain predominate during the early post-operative phase, while delayed union, non-union, recurrence of deformity, osteonecrosis of the proximal tibia, varus instability, patella baja and less commonly patella alta, hardware breakage, loosening or hardware related pain are encountered during the delayed post-operative period.

Rates of the more common complications include infection of 0.8 - 10.4%, symptomatic deep venous thrombosis of 2-5% in most series (Tunggal 2010), deep venous thrombosis by venography of 41%(Turner 1993), intra-articular fractures during HTLCWO of 0-20%(Tunggal 2010) and during HTMOWO of up to 11%(Hernigou 1987), lateral cortical hinge fracture of 35%, medial cortical hinge fracture of 55-82%, delayed union and non-union of closing wedge osteotomies of 4-8.5% and <1-5% respectively, peroneal nerve palsy post closing wedge osteotomy of 0-20% with up to 50% resulting in permanent deficit of varying severity (Tunggal 2010), less common complications include popliteal and anterior tibial artery injuries and compartment syndrome. Compartment pressures especially in the anterior compartment have been shown to increase following HTO, these pressures can be reduced by the use of a drain, thereby reducing the risk of compartment syndrome, which is therefore recommended (Gibson 1986).

The specific complications related to HTO typically compare the two most commonly used techniques, namely HTMOWO and HTLCWO, and the various means of fixation utilized. Broadly speaking, medial opening wedge is favored by some due to the reduced risk of neurovascular complications associated with the fibular osteotomy required during lateral closing wedge surgery, the reduced prevalence of compartment syndrome as the anterior compartment is not violated, and the fact that it is easier to perform through one incision allowing careful alteration of the extent of the correction intra-operatively prior to definitive fixation. Of 186 knees which underwent HTMOWO surgery and stabilization with a Tomofix® plate 10 (5.4%) went on to non-union. The identified risk factors for non-union were smoking, elevated body mass index and fracture of the lateral cortical hinge (Meidinger 2011). The lateral closing wedge is favored by others on the basis that the direct bone on bone contact provides earlier stability, faster osteotomy healing and permits earlier weight-bearing.

Individual studies report varying but nonetheless significant complication rates in association with these surgeries, for instance, in a prospective cohort study of 40 patients comparing HTMOWOs stabilized with a modified Puddu plate and grafted using tricalcium phosphate to HTLCWOs stabilized with an AO/ASIF L-plate, the overall complication rate was 55% in the Puddu plate group and 20% in the AO/ASIF L-plate group. This statistically significant difference in complications between the groups included 7 tibial non-unions and 6 hardware failures in the Puddu plate group and is accounted for by the rehabilitation

protocol which permitted full weight-bearing in both groups at 6 weeks. The authors suggest that a fixed angle device such as a TomoFix® plate might be a more suitable device for osteotomy fixation when an opening wedge technique is utilized (van den Bekerom 2008).

A single surgeon series of 194 osteotomies comparing HTLCWOs stabilized with two stepped staples and HTMOWOs stabilized with Aescula opening wedge plates, demonstrated overall and major complication rates of 27.9% and 16.4% in the closing wedge patients respectively, compared to 20.0% and 11.1% in the opening wedge patients. The actual major complications in the closing wedge group were 7 peroneal nerve injuries, 2 cases of compartment syndrome, one deep infection, 2 non-unions, one failure of fixation, 2 cases of loss of correction and 2 cases of varus instability. While the major complications in the opening wedge group consisted of two failures of fixation, 2 cases of loss of correction and 6 lateral tibial plateau fractures. These differences, however, did not reach statistical significance; nonetheless the authors recommend using the opening wedge technique. Obesity (BMI > 27.5 kg/m²) was found to be the only independent predictor of a major complication in this study, which excluded smokers (Song 2010).

Similarly, in an, in press, meta-analysis of 12 papers from 9 clinical trials comparing outcomes in opening (n=324) versus closing (n=318) wedge high tibial osteotomy surgeries, no difference in the incidence of infection, deep vein thrombosis, peroneal nerve palsy, non-union or rates of revision to knee arthroplasty could be demonstrated. No significant difference was found for any clinical outcome including pain, functional score or complications, medial opening wedge osteotomies, however, resulted in superior anatomical correction whilst simultaneously resulting in greater reductions in patellar height and greater increases in posterior tibial slope compared to closing wedge surgeries. The authors point out, that the reason no clinical difference in outcomes may have been identified may be due to type 2 error, failure to blind assessors and inadequate follow-up (Smith 2010).

5. Results of high tibial osteotomy

Apart from analysis of complications associated with the surgery itself probably the best, although crude, means available currently to assess the results of HTO surgery are through analysis of reported survival rates and patient satisfaction scores. Once again the largest series pertain to the patient with medial compartment overload treated with a HTMOWO or HTLCWO.

Lateral closing wedge surgery in 413 patients using a Krakow staple for stabilization yielded survival rates of 95%, 79% and 56% at 5, 10 and 15 years respectively, with 85% of patients being enthusiastic or satisfied with the surgery and 84% willing to undergo the surgery again at mean of 12 year follow up. Multivariate regression analysis also showed that patients aged less than 50 years, BMI < 25 kg/m² and ACL deficiency were all associated with increased odds of survival (Hui 2011).

In a study of 54 patients who underwent 55 HTOs, being either lateral closing wedge using a modified Weber technique and stabilized with a bent half tubular plate and 2 screws or medial opening wedge facilitated by release of the MCL and stabilized using a plate over a tricortical iliac crest bone graft, the 5, 10 and 15 year survival rates were 98%, 92% and 71%

respectively. The median follow up was 16.5 years (interquartile range (IQR) 14.5-17.9 years) satisfaction index was 80% (IQR 63-89), median knee injury and osteoarthritis outcome score was 71 (IQR 49-82) and median Western Ontario and McMaster university osteoarthritis index was 82 (IQR 66-96). There was no difference in survival rates or outcome scores when HTMOWO was compared to HTLCWO in this study but once again the study was likely underpowered to show any potential difference with fewer patients in the former group compared to the latter (Schallberger 2011).

One hundred patients retrospectively analyzed following HTLCWO surgery with stabilization using 2 staples exhibited a survival rate of 75% at 10 years with regression analysis showing higher likelihood of conversion to total knee arthroplasty (TKA) in females and patients whose Ahlback grade was ≥ 2 pre-operatively (van Raaij 2008).

Using Kaplan-Meier survivorship analysis, 73% of patients at 5 years, 51% of patients at 10 years, 39% at 15 years, and 30% at 20 years after high tibial osteotomy had not required conversion of a HTLCWO to a TKA; in 106 osteotomies in 85 patients with a minimum follow up of 10 years. Highlighting the importance of careful patient selection, on subset analysis of these patients, those under 50 years of age with a pre-operative flexion arc of greater than 120 degrees demonstrated much improved survival rates of 95% at 5 years, 80% at 10 years, and 60% at 15 years (Naudie 1999).

A HTLCWO stabilized using a Blount staple and AO semi-tubular plate and screws was used in 301 osteotomies available for follow-up at a mean of 18 years. The 20 year survival was 85% with revision as the end-point most likely in those patients aged greater than 50 years and with Ahlback arthritis grade ≥ 3 pre-operatively. Knee function was considered satisfactory in 77% of patients at final follow-up (Flecher X 2006).

HTLCWO has long been the gold standard and therefore the volume of literature currently available is weighted in its favour, however, this technique requires a fibular osteotomy and or disruption of the proximal tibio-fibular joint with their inherent risks to the peroneal nerve, lateral compartment muscle origin disruption, bone stock loss from the proximal tibia and a potentially more difficult conversion to TKA, for these reasons medial opening wedge techniques have gained popularity over recent years, especially since the development of fixed angled locking plates.

Using a medial opening wedge technique stabilized with a plate and screws and the gap filled posteriorly with a wedge of acrylic bone cement, Hernigou et al, demonstrated survival rates of 94% at 5 years, 85% at 10 years and 68% at 15 years, in 245 osteotomies in 197 patients with a mean age of 60 years (Hernigou 2001).

One hundred and twenty four HTMOWO osteotomies, performed in 110 patients with mean age of 53 years and mean follow-up of 10.4 years, grafted using a tricalcium phosphate wedge and stabilized using an AO T-plate, demonstrated survival rates of 89% at 5 years and 74% at 10 years. At final follow-up 88% classified themselves as satisfied or very satisfied with their outcome (Saragaglia 2011).

Two Japanese studies have shown superior survival rates at long term follow up; the exact role of cultural and ethnic factors in these studies is unclear, the results in this population nonetheless, speak for themselves. The first study used HTLCWOs stabilized using a Giebel plate, aiming for 10 degrees of anatomic valgus or placement of the mechanical axis within

the centre of the lateral compartment, in 118 knees in patients of mean age 62.9 years, whose mean flexion contracture was 7.7 degrees, with mean follow-up of 14.4 years. Using Kaplan-Meier survival analysis, the probability of survival was 99.3% at 5 years, 97.6% at 10 years and 90.4% at 15 years. The mean Hospital for special surgery score at final follow up was also deemed good or excellent in 73.7% of patients. Range of motion < 100 degrees and BMI > 27.5 kg/m² were associated with early failure, but interestingly, a pre-operative flexion contracture > 15 degrees and maximum flexion < 120 degrees showed a significant association with long term survival of the osteotomy (Akizuki 2008). The second study of 75 knees (60 female and 15 male) in 53 patients, in patients with a mean age of 59.6 years and mean fixed flexion contracture of 6 degrees, using HTLCWOs stabilized with either Charnley's external fixation clamps or a dual plating technique using a blade plate on the lateral side, demonstrated Kaplan -Meier survival rates of 97.8% at 5 years, 96.2% at 10 years and 93.2% at 15 years. In all patients walking distance was limited to less than 500m due to pain pre-operatively but had improved to greater than 1km without pain in 94.3% at 15-28 year follow up, at which time 98% were satisfied with their outcome (Koshino 2004).

6. High tibial osteotomy and conversion to total knee arthroplasty

One of the difficulties related to the decision as to whether to proceed with an osteotomy as against a primary arthroplasty procedure relates to concerns about conversion of that post-osteotomy patient to an arthroplasty should the patient require same in the future. This is based on the knowledge that osteotomy outcomes gradually deteriorate with time and therefore if a patient lives long enough they will likely require conversion to a TKA, which will be a more technically demanding operation than the standard primary TKA.

The difficulties encountered in converting a post-osteotomy patient to a TKA include initially ensuring there was no history of infection related to the metalwork required for fixation of the osteotomy. If there was a history of infection be it superficial or otherwise at the time of the osteotomy surgery it would be prudent to stage the conversion to TKA with removal of all retained metal work, appropriate culture of local soft tissue samples and normalization of blood work prior to proceeding with the definitive arthroplasty.

If there was no history of infection pre-operative planning should include templating to assess the need for removal of retained hardware. If removal of hardware is deemed unnecessary for tibial component placement, all tools for removal of retained hardware should be available at the time of surgery should the need arise. Whether hardware removal should be staged or not is often dictated by surgeon preference as opposed to hard data.

Pre-operatively, the knee range of motion should be assessed so that the surgeon will have an idea as to whether or not the patient might require an extensile procedure such as a quadriceps snip or tibial tubercle osteotomy to facilitate exposure of the joint. Similarly, patellar tracking and patellar mobility should aid in deciding on the need for lateral retinacular release or not. The previous incision should be taken into account when planning the approach to the knee, if a HTMOWO had been performed, this incision should not compromise the approach, however, when a lateral incision has been used for a previous HTLCWO care must be taken to ensure that either an adequate skin bridge is planned for or the two incisions converge at an angle no less than 60 degrees.

Radiographic analysis should examine the current alignment, with lateral or medial compartment opening on weight bearing perhaps indicative of ligamentous incompetence and raising the requirement for the availability of more constrained components at the time of surgery. The bone stock within the proximal tibia particularly on the lateral side, when a patient has had a HTLCWO should be carefully assessed; this should alert the surgeon to the possibility of the need for lateral augments and therefore stemmed tibial components. The geometry of the planned primary tibial component must be taken into account when analyzing the pre-operative radiograph to ensure the keel or pegs will not abut or breach the lateral cortex due to the relative medialisation of the medullary canal following HTLCWO, if this is likely to be a problem consideration should be given to, downsizing and medialising the tibial component, use of a system with shorter tibial pegs or studs or the use of stemmed revision components to offset the tibial tray from the stem. The lateral radiograph is important in assessing the posterior tibial slope and the height of the patella, with patella baja alerting the surgeon to possible difficulties in everting the patella; this is especially relevant when the patient has had a HTLCWO and immobilization post-operatively. Restoration of the posterior tibial slope is important in ensuring flexion and extension gap symmetry as well as in preventing impingement of the tibial component keel on the anterior cortex of the tibia in the case of excessive posterior slope.

Most of these problems are less of an issue following HTMOWO, due to the fact that bone stock is preserved, the fibula has not been disrupted or osteotomised and therefore gives a definite guide to joint line restoration and tibial component rotation, the medullary canal has not been medialised and as long as care has been taken to ensure the primary correction at the time of the osteotomy occurred through opening of the wedge posteriorly, patella baja should also be minimized.

Even though these technical difficulties are present during the conversion of a post-osteotomy knee to a TKA, studies to date have failed to show that this has a deleterious effect on outcomes. In a systematic review of the published literature up to September 2007, 17 studies met the inclusion criteria but pooling of the data was not possible due to the heterogeneity of the studies. Malalignment and instability are major causes of early failure following TKA with most revisions performed within 5 years, with a median follow-up of 5 years in eight included studies reporting on revision surgery no significant differences in TKA failure for the patients receiving TKA after previous osteotomy compared to primary TKA was identified in this review. This review concluded that the use of HTO postpones primary TKA for a median of 7 years in younger patients. Six studies that reported knee range of motion reported median reductions of 10 degrees for patients receiving TKA after HTO compared to primary TKA patients. At mid-term follow-up in eight out of nine studies reviewed significant differences in overall function evaluated by standard knee clinical scores could not be shown between the groups (van Raaij 2009). Since this review a number of studies as outlined below, detailing similar findings, have been published.

A study of 29 knees in 24 patients, who underwent 19 HTLCWOs and 10 HTMOWOs, matched to a control group of 28 patients with 29 knee arthroplasties for age, pre-operative American knee society score and radiographic AP alignment as well as length of follow-up (97 months), failed to show any difference in patient satisfaction between the groups with

96.5% of patients in both groups having a good or excellent result at this time point. The authors report that prior HTO did not adversely affect component fixation, but at final follow-up there were significantly more radiolucent lines under the tibial components on lateral radiographs in the study group and one patient had gone on to revision at 37 months for aseptic loosening. Additional techniques to facilitate exposure were required in 7 patients being 3 quadriceps snips, 3 lateral releases and 1 tibial tubercle osteotomy. The Caton index was also significantly reduced in the study group post-operatively, in which 3 patients required subsequent patella resurfacing at 18, 19 and 27 months with the authors suggesting that primary patella resurfacing be considered in these patients to reduce rates of anterior knee pain (Amendola 2010).

In a study of 48 patients who underwent TKA after HTLCWO with a mean follow-up of 13.3 years, the mean knee society score increased from 90 pre-operatively to 160 post-operatively, with the authors concluding that prior HTLCWO did not affect the clinical and radiological results of TKA in the longer term (Treuter 2011).

From an original study group of 39 patients who underwent bilateral TKA using cruciate retaining components, at a mean of 8.7 years post unilateral HTLCWO, 20 patients had died leaving 19 patients available for follow up at a mean of 14 years post total knee replacement. There was no significant difference in Knee society or pain scores between the knees, no femoro-tibial revisions had been performed in any knee at final follow-up (Meding 2011).

Matched-pair analysis was used to minimize the effect of variables such as age, gender, follow-up, etiology and prosthetic design in comparing the results of 41 primary TKA patients with 41 patients who underwent TKA using a cemented posterior stabilized design without patella resurfacing, following HTLCWO. Although 3 patients required lateral releases and 1 a medial tightening there was no difference in mean operative time between the groups. Complication rates of 19.5% in the study group (including 4 patients with wound necrosis at the level of the previous lateral incision) and 4.8% in the control group were not statistically different. At final follow-up, at a mean of 82 months in the study group and 85 months in the control group, range of motion was reduced in the study group compared to controls (pre arthroplasty range of motion was not available for either group) and other than a reduced knee score of the knee society score there was no difference in VAS, WOMAC, Lequesne, UCLA, Feller's Patellar Score and SF-36 scores. There was no difference in component alignment or rate of radiolucencies detected at final follow up between the groups and no patient had undergone femoral or tibial component revision (Efe 2010).

7. Conclusions

High tibial osteotomy is an effective and successful procedure; it demands meticulous surgical technique to limit complications and achieve correct post-operative alignment. Where these techniques and goals are adhered to enduring long term results and high satisfaction rates in carefully selected patients are to be expected. It's use should not be avoided by the surgeon for fear of difficulties relating to conversion to total knee arthroplasty especially if medial opening wedge techniques are used, since to date outcomes

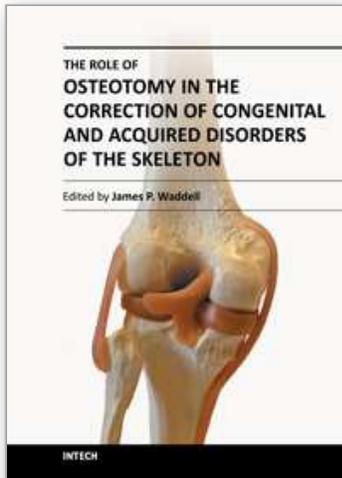
are comparable in primary arthroplasty patients when compared to those undergoing arthroplasty following high tibial osteotomy.

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The Role of Osteotomy in the Correction of Congenital and Acquired Disorders of the Skeleton

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This book demonstrates specific osteotomy techniques from the skull to the hallux. The role of osteotomy in the correction of deformity is under appreciated in part because of the ubiquitous nature of joint replacement surgery. It should be remembered, however, that osteotomy has a role to play in the correction of deformity in the growing child, the active young adult, and patients of any age with post-traumatic deformity limiting function and enjoyment of life. In this text we bring you a number of papers defining specific problems for which osteotomy is found to be an effective and lasting solution. I hope you find it useful.

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