Review Article
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Current Concepts in High Tibial Osteotomy

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Abstract

Background: High tibial osteotomy is an effective procedure for the management of medial compartment osteoarthritis. This paper intends to analyze the current indications, contra indications, technique, complications, survival, and recent advances of this procedure.

Method: Literature review was done by searching journals with "High tibial osteotomy," "Indications of HTO," "Alignment in HTO," "Survival and clinical outcomes of HTO," and "Recent advances in HTO." A total of 12 articles were found suitable for this study and reviewed.

Outcomes: Indications have largely remained the same except for thrust, which was earlier, a contra indication, Biplanar osteotomy, patient specific instrumentation; 3D printing and computer navigation are the recent technical modifications. The rate of complications is variable in different studies and the 5-year survival is still over 90% in most studies. Rate of serious complications is low but minor complications are high.

Conclusion: HTO is a successful procedure in treating medial compartment OA in isolation or with ligament deficiencies with a good 5 and 10-year survival. Recent advances have focused on improving planning, rehabilitation, and accuracy of alignment.

Keywords: High Tibial Osteotomy, osteotomy, deformity, gene varum, osteoarthritis, knee preservation, deformity correction.

Introduction

Treatment of a young arthritic knee is always challenging and knee preservation surgery always takes precedence in this age group. Re-alignment surgeries like a high tibial osteotomy (HTO) are reserved for cases where the arthritis is restricted to the medial compartment with the principle being to unload the medial diseased compartment [1, 2]. Indications for the same have been the same over the years with minor modifications from time to time. However, it is a matter of debate as to how much correction is ideal with some advocating a neutral alignment to a few degrees of valgus in the coronal plane. However, to achieve the intended alignment modern techniques of computer-assisted surgeries and patient specific instrumentation are used and have proven to be useful. Effects of the HTO on patellar biomechanics can potentially affect long-term outcomes and are a factor considered while choosing the technique, especially in larger corrections [3, 4]. Alignment in the sagittal plane is critical especially in cases of associated ligamentous instability and more attention is being given to this aspect in current literature. Concomitant meniscal, chondral, and ligament surgeries may be performed with the HTO depending on patient symptoms and clinical as well as radiological findings (my publication) [5].

Methods of performing the osteotomy vary from open wedge to closed wedge osteotomies and rarely dome osteotomies. In the past, closed wedge osteotomies were more popular but in recent times there has been a preponderance of open wedge osteotomies with each of the techniques having their own advantages and disadvantages [6]. Once the osteotomy is done, fixation of the same can be done with various internal fixation devices and each of these having their own advantages. However, the ideal osteotomy technique and device to fix it are questionable [7].

Survival and clinical outcomes of HTO are important and data seem to suggest that HTO has a favorable outcome with both in long-term follow-up. However, various patient and surgical factors seem to influence this [8].

Rehabilitation post-HTO has evolved with time and accelerated protocols in place now due to stronger implants and modified techniques allowing early mobilization and weight bearing. These accelerated rehabilitation protocols have facilitated bilateral HTO's in the same sitting (my publication) [9].

The intention of this review is to analyze the two most widely performed techniques of osteotomy (Closed and open wedge) as well as the current indications, contra indications,

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prognostic factors, survival, clinical outcomes, complications, and recent advances in osteotomies.

Evolution of Indications

One of the currently acceptable criteria to do a HTO is the ISAKOS criteria. The indications according to it are isolated medial joint line pain in a patient between 40 and 60 years with a BMI < 30, a high demand person except those who are into running and jumping. A maximum malalignement of 15 deg metaphyseal varus with full range of motion (ROM) of the knee and a normal lateral and patellofemoral compartment. Contraindications are rheumatoid arthritis and an axial deformity of more than 20 degrees [10]. However, older studies have contraindicated the procedure in those with Fixed flexion deformity (FFD) >15 deg, greater than 1 cm lateral tibial thrust, chronic smokers, and severe medial compartment OA (Ahlback III) or bone exposure on either surfaces apart from the above contraindications [11, 12, 13, 14, 15, 16, 17, 18, 19].

Imaging Modalities

The imaging modalities used to evaluate the degree of medial compartment OA apart from standard AP, lateral, and skyline views of the knee are the bilateral weight bearing Hip Knee Ankle X-ray to assess knee alignment [20]. Single leg standing long leg films are particularly useful in cases of suspected lateral ligament laxity in isolation or associated with medial compartment osteoarthritis [21]. CT scanograms have also been used but lack accuracy, as they do not take into consideration the alignment of the knee while weight bearing [22]. Arthroscopy done before the osteotomy is particularly useful in accurately determining the grade of osteoarthritis in individual compartments and is both diagnostic and therapeutic as concomitant meniscus; ligament and chondral pathologies can be addressed with the osteotomy [23, 24].

Patient Characteristics

Best results are in patients < 55 years of age. The relative risk increased with patients over the age of 65 years. A BMI of <27.5 gives best patient reported outcomes [25]. When the BMI is >30, there is relative risk of early failure and worse PROM's at 5 years follow-up. ROM of < 90 relates to a higher failure rate [26]. A flexion deformity of 5^0 that is associated with a ROM <120^0 pre-operative in a patient has a poor prognosis [12]. Heavy smokers have a worse prognosis [11, 12, 13, 14, 15, 16, 17, 18, 19, 27, 28, 29, 30, 31, 32].

Concepts on Biomechanics

The normal anatomic axis is about 5–7 degrees valgus with the articular surface of the tibia being in 2-3 degrees valgus relative to the mechanical axis [33]. About 55–70% of the knee load is transmitted to the medial compartment during the stance phase [34]. Even a 1 deg varus increases the medial load by 5% [35]. Varus alignment greater than 2 degrees increases the probability of osteoarthritis [36].

Changing the line of weight bearing has been shown to not only unload the affected compartment but also facilitate repair of the cartilage [37, 38, 39, 40]. The change in alignment is favorable to the chondrocytes, which, in turn , helps in cartilage repair. Kim et al. also demonstrated that there is macroscopic repair of cartilage even without concomitant menisci or chondral procedures [41]. Correction in malalignment has been shown to have an effect on the failure of the menisci, cartilage, and ligaments. Malalignments that were not treated initially largely contribute to failure of the index procedure [42]. When HTO's are done in cases of instability, specific techniques have certain advantages. In a posterior cruciate ligament (PCL) deficient knee, increase in the slope of the osteotomy is beneficial. Hence, open wedge osteotomies are useful here. On the contrary anterior cruciate ligament (ACL) deficient knees benefit from a reduction in slope hence a closed wedge osteotomy works well to do this [43, 44, 45].

Open wedge osteotomies cause a reduction in patellar height and hence can be detrimental in cases of existing patella baja where open wedge osteotomies are better [4]. The gait is also modified after osteotomies and very few studies have investigated this. In open wedge osteotomies, there is an increased flexion and internal rotation in level walking and on ascending stairs. It also reduces knee adduction moment without necessarily decreasing the force on the medial compartment [46, 47, 48, 49].

Techniques of Osteotomy

The two most widely used techniques are the open and closed wedge osteotomies. There are other less popular techniques that we will not discuss in this paper. The open wedge osteotomy is the most widely used and popular techniques these days with distinct advantages and some disadvantages [50, 51, 52]. Slope correction especially in PCL deficient knees are a lot easier as this technique has a tendency to increase the slope. The downsides of the open wedge osteotomy are the possibility of collapse or loss in correction, non-union, and the requirement of a bone graft. The closed wedge osteotomy has the advantage of being a slope reduction osteotomy, helping ACL deficient knees. It also does not need a bone graft hence chances of non-union are less. However, there are certain distinct disadvantages such as violating the tibio fibular joint and requirement of a fibular osteotomy [53, 54, 55, 56]. It also requires the dissection of the common peroneal nerve as the osteotomy is done from the lateral side [57]. Removal of a piece of bone reduces the bone stock and hence can cause shortening of the limb [54]. This technique though reduces the slope, control of slope correction is less and hence technically more difficult in correcting ligament deficiencies along with axis correction [20]. Isolated slope correction osteotomies are not yet an established procedure in isolated ACL instability. However, they are an established procedure for posterior and posterolateral insufficiencies in the presence of genu recurvatum [58]. It has been suggested that for optimum maintenance of correction and slope in an open wedge osteotomy, the osteotomy should be parallel to the joint line; the posterior corticotomy should be complete with adequate posteromedial soft-tissue release so that the osteotomy opens up adequately. The plate should be positioned as posterior as possible. The anterior gap, behind the tibial tuberosity should be 67% of the posterior gap for optimization of the slope [59]. The biplanar osteotomy has the advantage of preserving the anterior and lateral cortices and the usage of a strong medial plate circumvents the requirement of a bone graft [60]. The cable and grid methods are most commonly used for intra-operative assessment of correction in non-navigated HTO's [61, 62].

Degree of Correction

There has been considerable amount of debate on the optimal level of correction. However, there is no consensus as to the optimal degree [59]. Fujisawa postulated that the best results are obtained when the mechanical axis passes through 30–40% of the tibial plateau and postulated 62.5% of the mediolateral width of the tibial plateau to be ideal [63]. Miniacci postulated that the mechanical axis should pass through 60–70% of the tibial plateau measured from the medial plateau [64, 65]. Jacob and Murphy modified Fujiswa's recommendations depending on the severity of the disease. In minimal osteoarthritis, the mechanical axis should pass through 1/3 the distance to the Fujisawa's point and in severe osteoarthritis to the Fujisawa's point [66]. Best outcomes have been seen with an average over correction of 3 degrees [67, 68].

Implants used in HTO

Implants used in this procedure vary from strong locking plates, PEEK power plate, smaller plates such as the Puddu plate and even external fixators and plasters in closed wedge osteotomies with each having distinct advantages and disadvantages. However, the superiority of one over the other has not been conclusively established. Static compression load to failure tests revealed sufficient stability up to 2400N without fracture of the opposite cortex [69, 70, 71]. Locking plates such as the Tomofix have the distinct advantage of having a high tensile strength permitting early weight bearing; however, they can cause hardware related complications warranting a relatively higher rate of implant removal. The concept evolved around the philosophy that interfragmentary motion rather than high mechanical strength more important for bone healing [72, 73]. In the background of a biplanar osteotomy, they may be used for large corrections without a bone graft [60]. The PEEK locking plates and the i balance PEEK system are newer designs. The smaller PEEK devices may not be used for larger corrections as they are not as strong as the larger locking plates. The PEEK plate and screw system are being used for larger corrections; however, longer follow-ups need to establish its results in comparison to the Tomofix [74]. External fixators both circular and linear have been used for large corrections with potential advantages of early weight bearing. However, external fixators are bulky and can cause pin site infections [75]. A cost-effective technique of treating patients undergoing closed wedge osteotomies is applying a long leg plaster for 6 weeks; however, they potentially cause stiffness in the knee at the end of the convalescence [76]. Highest fatigue to failure screw breakage test was lowest for the i balance. Highest fatigue strength was found to be in Tomofix, i balance, and contour locking plate. It was lowest for the PEEK power plate [74].

Concomitant Procedures

Doing an arthroscopy before an osteotomy is not absolutely indicated. However, advantages are that concomitant lesions such as a chondral/meniscus or ligament lesions can be addressed simultaneously as well as it acts as a diagnostic modality by grading the degree of OA individual compartments. HTO combined with micro fracture, ACI improved outcomes [77, 78, 79, 80, 81, 82]. Doing an HTO with cases that have had medial meniscus transplants have better patient reported outcomes [83].

Recent Advances

The recent advances in HTO are not pertaining to just the introduction of new implants such as the PEEK power plate and i balance system but also with regards to the way the procedure is performed. Computer navigation has been introduced to increase accuracy, as up to 20% cases done do not give the desired alignment post-operative [29, 84]. The ortho pilot, vector vision, and surgigate systems are available navigation systems that have been studied [85]. Akamatsu studied the effects of navigation on HTO and found navigated HTO's had better alignments both in the sagittal and coronal planes but this did not translate into better patient reported outcome measures and nor were the complication rates any different [86]. The advantages of navigation are that the accuracy is better both in the sagittal and coronal plane and it does compensate for the lack of pre-operative surgical planning. However, it does have a longer learning curve, infection, and fractures due to the pins can happen, the surgical time is longer and potentially the added cost [87].

Patient specific instrumentation (PSI) and 3 days printing have been used in HTO's. Virtual osteotomies can be performed on saw bone models produced by 3D printing using the patients CT scans before doing the actual osteotomy. This helps in titrating the amount of correction in vitro before it is done in vivo [88].

PSI has varied designs, those that guide placement of drill holes on the tibia based on local bone references. The saw cut is performed through a guide and opened up till the plate holes align with the holes made on the tibia. However, this technique has the potential disadvantage of requiring a large incision [88]. The Embody design relies on distant bony landmarks such as the medial, lateral malleoli, and the fibular head. The advantage is that this system requires a smaller incision, however may be less accurate than the former system [89]. Novel low radiation CT scans have been introduced that are comparable to standard long leg X-ray [90].

Complications

The rate of serious complications is low but minor complications may be high. Complication rates as high as 31% have been reported with non-union rates varying from 0.7 to 4.4% [91, 92]. Woodacre reported an infection rate requiring hospitalization of 3.5% [91]. External fixators had an infection rate of 2.3–54.5% versus <4% in those that were fixed with internal fixation devices. Non-union rates are to some extent influenced by implant type with locking compression titanium plates having a non-union rate of 3.6% versus 8.3% overall in one study [20]. Causes of non-union are excessive correction, smoking, and poor fixation [93]. The incidence of Patella baja was 7.6–8.8%. Common peroneal nerve palsy was another complication seen in lateral closing wedge osteotomies with an incidence of 16–20% and minimized by doing a concomitant fibular shaft osteotomy. Other complications were those of loss of correction, compartment syndrome, DVT, pulmonary embolism, and pseudoarthroses [20].

Survival and Clinical Outcomes

There have been multiple studies that have evaluated 5, 10, and 15-year survival of HTO's. The 5-year survival in both open and closed wedge varies from 90.0% to 98%. De Meo demonstrated a survival of 70 % in his series of medial opening wedge osteotomies at 8 years. The 10-year survival varies from 60% to 92% at 10 years. Only one study has evaluated 15-year survivals that were at 71% [8].

Discussion

HTO's have been traditionally done in medial compartment osteoarthritis [1, 2]. However, their indications have now been extended to ligament deficiencies in the coronal and sagittal plane as well as combination of medial compartment OA with ligamentous deficiencies. The philosophy behind it being that unless the alignment is conducive to ligament reconstruction and in chronic ligament tears biomechanically compensates for its deficiency [43, 44, 45]. The biological age of the joint is critical rather than the age of the patient [81]. The procedure possibly is done best in patients <55 years as the healing potential and quality of the bone is possibly better at a younger age. Furthermore, the ability of the patient to cope with a longer convalescence being better as the patient is younger [11, 94, 95, 96] Smoking in general delays healing and hence is a negative prognostic factor [93]. The heavier the patient, the larger the forces that pass through the knee and hence the rate of progression of arthritis being potentially faster. Apart from that the greater load passing through the knee in a heavier patient can potentially cause early failure or loss of correction [11, 12, 25]. Imaging modalities have developed and the latest low dose radiation CT scans are comparable to the long leg scanograms vis a vis the amount of radiation [90]. However, for planning the long leg weight bearing radiographs allow for more accurate planning. Single leg stance radiographs are useful for cases where we suspect ligament deficiencies in the coronal plane [21].

The medial opening wedge technique has taken precedence over the lateral closing wedge osteotomies mainly as the titration of slope especially in PCL deficient knee is better done. The other advantages being that it does not violate the proximal tibio fibular joint that does contribute to some stability. The closed wedge osteotomy causes shortening and can potentially cause common peroneal nerve palsy, as it requires dissection. The Biplanar osteotomy, a modification of the medial opening wedge allows for early weight and union as the anterior and lateral cortices are intact [60]. This has facilitated bilateral simultaneous HTO's too [9]. The degree of correction has been a controversial issue with different postulations. However, the best patient reported outcomes have been with an over correction to 3 degrees of valgus [67, 68]. The possible reasons for the same could be that the line of weight bearing is completely transferred to the lateral normal compartment. Implant modifications have also happened with radiolucent implants made of PEEK like the i balance system which is completely radiolucent [97]. The Tomofix is a strong locking plate device and with the biplanar osteotomy allows for early weight bearing (my study) [9]. Concomitant cartilaginous and meniscus procedures improve PROM's as at times cartilaginous flaps and meniscus tears potentially causes mechanical symptoms and taking care of them helps [5]. Apart from that the possibility of fibrocartilage/ hyaline such as cartilage being formed by cartilaginous procedures potentially reduces the pain even if some amount of weight continues to pass through the affected compartment. Ligament reconstructions especially help in those cases where there is an instability associated with medial compartment OA hence better patient reported outcomes [58]. Navigation has been shown to produce better alignments; however, this has not translated into better patient outcomes. This is possible due to shorter follow-up studies. Achieving a good alignment would potentially lead to a longer survival and hence navigation is a useful tool [87]. Virtual osteotomies using 3 D printing potentially helps in better planning preoperatively and is a very useful tool. However, it does increase the cost of the procedure [89]. Survival of the procedure is very good for 10 years; however, some long-term studies show a significant decline in 15-year survivals. This could be the reason as HTO is a re alignment procedure that intends to transfer the body weight to the lateral normal compartment [8]. Up to 20% of cases do not achieve the intended alignment and hence when this happens, due to non-physiological loads passing through the opposite compartment or some load continues to pass through the diseased compartment; it potentially degenerates further over a period of time [29]. The other possible cause being due to progression of osteoarthritis in general to the rest of the knee. There is however a lacuna in literature on gait changes post-HTO as well as studies evaluating how close the final alignment is to the intended alignment. Changes in gait can affect the joint above and below and possibly cause unusual loading of these joints that may lead to future consequences in them. Reporting of how close to the intended alignment is the key to assess the accuracy of the reproducibility of the technique [49].

Conclusion

HTO has good results in the short and medium term and is a useful procedure in specific indications. Concomitant procedures improve the results in HTO and hence an arthroscopy pre osteotomy helps. Use of navigation gives better alignment and requires less planning pre-operative. Navigation and patient specific instrumentation improve accuracy as well as planning but add to the cost of the procedure. The optimal correction is controversial but alignment correction in a few degrees of valgus unloads the affected compartment and gives better patient reported outcomes.

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