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Planning for a Successful High Tibial Osteotomy

Hamid Razak[1, 2], Kristian Kley[3, 4]

Abstract

High tibial osteotomy (HTO) has been the workhorse joint preserving surgery for medial knee osteoarthritis (KOA) with varus deformity. Its importance as a surgical option has been amplified in recent years due to the greater incidence of KOA in young active patients. HTO procedures produce the best outcomes and the highest predictability when executed according to the pre-ordained surgical plan. Planning for an HTO is a mandatory and critical step. Failure to plan adequately leads to poor outcomes following HTO. Methods of planning can be broadly classified into traditional pen-and-paper planning as well as digital planning with software. Both are acceptable methods with their own merits but their utilization may be influenced by surgeon preferences, accessibility, case load and experience

Keywords: Varus knee osteoarthritis, Knee preservation, High tibial osteotomy, Preoperative planning, Surgical planning

Introduction

"A goal without a plan is just a wish," is an adage attributed to Antoine de Saint Exupéry, the 20th century writer, poet, aristocrat, journalist and pioneering aviator. This applies to high tibial osteotomy as well. To achieve the goals of high tibial osteotomy (HTO) without a plan is mere wishful thinking. HTO has been a viable treatment for medial knee osteoarthritis (KOA) for decades, if not centuries [1]. Nevertheless, HTO in the last 40 years has not been regarded as the gold standard of surgical treatment of osteoarthritis. Many national registries in the last decades have reported plummeting figures in terms of HTO utilization rates in comparison to that of total knee arthroplasty (TKA) [2]. There has been a renaissance of HTO surgery in recent times due to the increasing awareness of the unpredictable outcomes and failure rate of TKA, especially in younger patients [3]. Orthopaedic surgeons are refocusing their efforts in understanding the principles of HTO and it is becoming an accepted part of the surgical armamentarium in the treatment of KOA again. As a result, there has been an acceleration in research and innovation of the surgical techniques pertaining to HTO in the recent years. It has been shown that osteotomies produce the best outcomes and the highest predictability when executed according to the pre-ordained surgical plan [4]. In this article, we will review the importance of planning for a HTO, describe the widely accepted methods of planning, and provide an analytical comparison of traditional pen-and-paper versus digital planning.

Importance of Planning

When an Orthopaedic Surgeon encounters a patient with a malalignment, the analysis of the malalignment starts with firstly the history given by the patient. Subsequently, the surgeon performs a physical examination to further characterize the malalignment and/or the deformity. He/she then orders relevant imaging investigations to complete the analysis. While analysis of the malalignment technically should be conducted much earlier as described above, it is often realistically postponed to being conducted together with the planning. This makes planning for a HTO even more important as failure to plan may lead to an incomplete analysis of the malalignment and perhaps even to wrong surgery being performed. In a coronally varus malaligned knee, the deformity may not always be in the proximal tibia. At times, the deformity may be in the distal femur necessitating a distal femoral osteotomy (DFO) instead [5]. A surgeon who fails to plan might end up performing a HTO for a patient with distal femoral varus and in the process cause a new extra-articular deformity instead! It has been well reported that pre-operative planning for the appropriate correction gap and angle in HTO has a significant effect on its outcomes [6-8].

Orthopaedic surgery in general has seen a significant advancement in technology and techniques along with a widening array of implants and devices over the past decades. This is particularly relevant to osteotomy surgery. To some extent, this may have contributed to

[1]SingHealth Duke-NUS Musculoskeletal Sciences Academic Clinical Programme 20 College Road, Academia Level 4, Singapore 169865.
[2]Department of Orthopaedic Surgery, Sengkang General Hospital 110 Sengkang East Way, Singapore 544886.
[3]London Osteotomy Centre, Harley Street Specialist Hospital, 18-22 Queen Anne Street, London.
[4]Orthoprofis Hannover, Luisenstraße 10-11, 30159, Hannover, Germany.

Address of Correspondence:
Dr. Hamid Razak,
Department of Orthopaedic Surgery, Sengkang General Hospital 110 Sengkang East Way, Singapore 544886.
E-mail: hamidrazak@gmail.com


Dr. Hamid Razak


Dr. Kristian Kley

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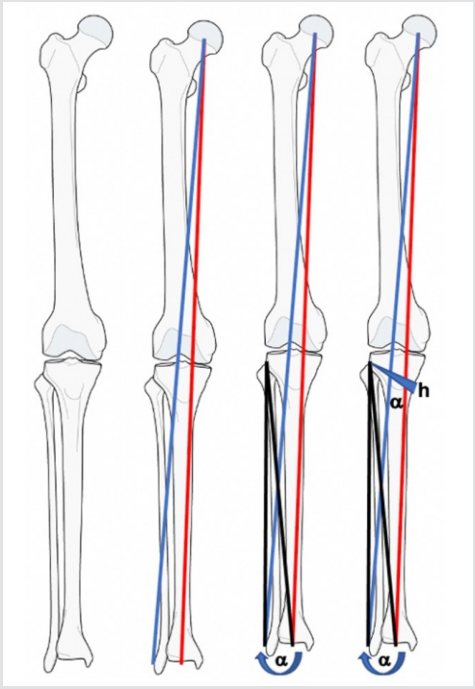

Figure 1: Planning steps for the Miniaci method as described in the text.

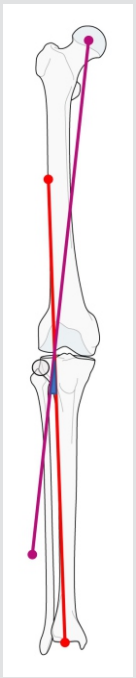

Figure 2: Obtaining angle of correction (blue triangle) using Dugdale method

increased associated risks and complications resulting in higher rates of potential patient dissatisfaction and litigation [9]. Some of the main reasons for medicolegal claims have been wrong diagnosis, failure to interpret X-rays, inappropriate treatment and intra-operative problems [9]. All these problems can be mitigated effectively by proper preoperative planning, especially where osteotomy surgery is concerned. In the current medicolegal climate, it is paramount that every osteotomy surgery is carefully and appropriately planned for to avoid disasters in the operating theatre.

Communicating with patients prior to their surgery is a key feature in the pre-surgical phase. It is imperative that patients are given the appropriate period to consider the relevant information and guidance pertaining to the surgery they are being planned for [10]. Where osteotomy surgery is concerned, pre-operative planning especially on digital platforms may be useful in pre-operative patient communication. The surgical plan may be used as an adjunct in patient communication so that the patient has a clearer understanding on what he/she may expect following surgery.

Methods of Planning

Miniaci method

Miniaci et al proposed a trigonometric method to measure the pre-operative correction angle for HTO (Figure 1) [11]. This method has been widely adopted and applied by surgeons worldwide. The first step in the Miniaci method is draw the Mikulicz line, which starts at the centre of the hip joint and ends at the centre of the ankle joint [12]. The location of the Mikulicz line and the hip-knee-ankle (HKA) angle can be used to accurately analyze the knee deformity in the coronal plane, based on whether the line lies medially (varus deformity) or laterally (valgus deformity). In the next step, the desired passing point of the weightbearing line post-osteotomy is defined. Fujisawa et al described in their study that the ideal correction method is to align the mechanical axis to pass through a point 30 to 40% lateral to the midpoint [13]. This approximates to a point 65 to 70% from the medial border of the tibial plateau. Subsequently Dugdale et al proposed that the ideal point should be 62% from the medial border of the tibial plateau [14]. However, in recent times aiming for the lateral tibial spine (50% to 55%) has shown better joint geometry and lesser patellofemoral joint problems following HTO [15]. Subsequently, the native and post-osteotomy positions of the ankles are projected. The lines between those two points define the correction angle required for the osteotomy at the hinge position the lateral cortex of the proximal tibia. There have been several suggestions for the ideal position of the hinge [16-18]. Recently, Nakamura et al concluded that the most appropriate hinge position for prevention of unstable lateral hinge fractures for medial opening wedge HTO should be within the projection of the proximal tibiofibular joint (PTFJ) and lateral to the medial margin of the PTFJ [19]. On a calibrated long leg film, the earlier obtained correction angle is projected at the proximal tibia and the osteotomy gap is measured at the medial aspect of the tibia. For reproducibility and precision, these long leg films have to be taken in the anteroposterior projection with the following criteria: (i) both patellae facing forwards, (ii) the overlap of the fibula head in the proximal tibiofibular joint should be approximately one-third, (iii) the femoral condyles should be aligned straight and not curved, and (iv) the films have to be taken with the patient bearing weight so that intra-articular wear and deformity can be accounted for in the planning.

Dugdale method

Dugdale et al described another method to calculate the tibial wedge size in preoperative planning for HTO [14]. In the Dugdale method, first a line is drawn from the hip centre to the desired correction point on the tibial plateau. Then, another line is drawn from the ankle centre to the desired correction point. The angle subtended by these two lines is then taken as the correction angle.

Sivertsen et al compared the planning methods of Dugdale and Miniaci for HTO and concluded that the Dugdale method is more

Figure 3: HTO planning using traditional pen-and-paper method on a calibrated long leg film

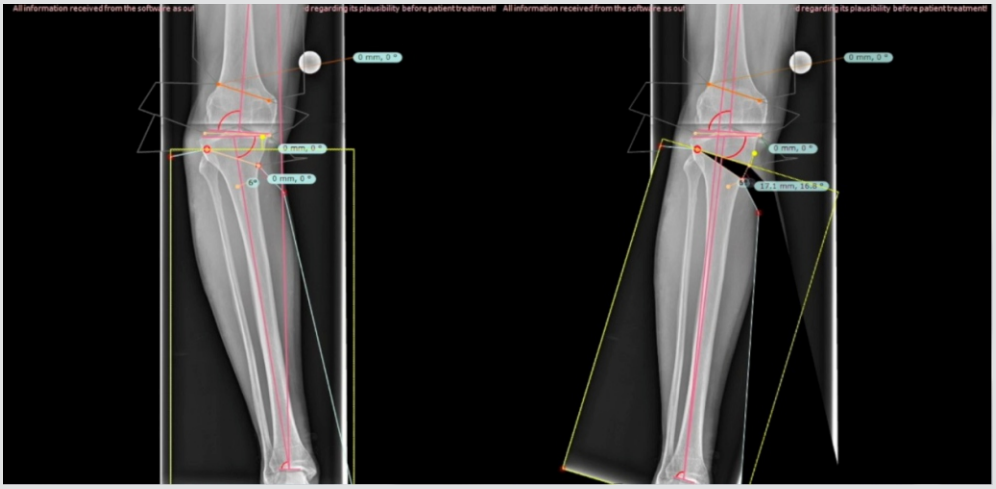

Figure 4: HTO planning using digital method showing pre- and post-osteotomy alignment

likely to underestimate the correction compared to the Miniaci method [20].

Traditional versus digital planning

Planning for HTO can be undertaken in the traditional manner, using pen and paper (Figure 3) or via digital planning software (Figure 4). Traditional planning necessitates printing of a calibrated long-leg film on paper with preserved aspect ratios. The surgeon can then apply the Miniaci or Dugdale methods as described above to "perform" the osteotomy on paper and measure off the osteotomy gap. The surgeon then attempts to replicate this in the operating theatre. In digital planning, several methods are available. The Miniaci and Dugdale methods can be undertaken using digital radiographic images using the picture archiving and communications system (PACS). This is delivered through various similar software portals which allow annotation of radiographic images. Elson et al described a modified Miniaci method for use with a digital PACS viewer and reported good reliability [21]. In higher volume centres, highly reliable landmark-based digital planning software such as The HTO Pro® (Fowler Kennedy Sport Medicine clinic, Ontario, Canada), AutoCAD® (Autodesk Inc, San Rafael, CA, USA), mediCAD® (Hectec GmbH, Germany), PreOPlan® (Siemens, Germany/Synthes, Switzerland) and TraumaCad® (Brainlab AG, Germany) are used. However, these softwares may not be readily available to all surgeons wishing to perform a HTO. Therefore, the traditional method of planning for an HTO on paper remains relevant. In more recent times, there have been mobile applications developed for osteotomy planning such as Bone Ninja and Osteo Master. The pros and cons of traditional versus digital planning for osteotomy has been summarized in Table 1.

Yoon et al compared a traditional method of planning for HTO with a digital method using PACS and found that correction based on the Miniaci method using PACS was more accurate [22].

Traditional planning	Digital planning
Pros:	**Pros:**
* Cheap * Ensures that the surgeon learns and understands the basic concept of an osteotomy * Universally available without the need for software and/or hardware requiring only a printed radiograph, ruler, protractor and a pen/pencil	* Direct PACS connection allows the plan to be viewed in the operating theatre * Greater precision * Saves time (after initial investment of time to learn software) * May enable surgeon to analyze and discover another level of deformity * Allows surgeon to distribute the deformity on multiple levels i.e. double level osteotomy * Serves as a digital proof in medicolegal cases * Opportunity to integrate artificial intelligence and machine learning techniques i.e. PeekMed®
Cons:	**Cons:**
* May be time consuming if double/multiple level osteotomy is planned * Precision of plan depends on calibration and scale of radiograph	* Cost * Initial time investment for learning * Over-reliance may blunt understanding of basic concepts of an osteotomy * Less accessible (may be negated by mobile applications)

Table 1: The pros and cons of traditional versus digital planning for osteotomy

Conclusion

Planning for a HTO is mandatory to achieve good outcomes and avoid complications. Both traditional pen-and-paper and digital methods are accepted for planning with no superiority of one over the other in terms of achieving the goals of HTO. However, surgeon preferences, accessibility, case load and experience may influence the method adopted. For surgeons starting off on their osteotomy journey, we would be recommended traditional methods of planning as a means to understanding the concepts and principles of HTO.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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