# The 5th Global Conference on Biomedical Engineering (GCBME 2022)

# Development of Surgical Planning and Patient Specific Instrument for High Tibial Osteotomy Surgery

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## Introduction

### Motivation & Purpose

Knee osteoarthritis is one of the common aging problems[1]. The knee joint bears the weight of the entire body during activities. Due to aging, muscle support around the knee joint may decrease or the ligaments relax[2]. Personal activity habits that the knee joint is in a high-intensity weight-bearing state for a long time, which gradually wears the surface of the knee joint, cause the knee joint to gradually degenerate, resulting in decreased range of motion or pain[3].

High tibial osteotomy is one of the methods used to treat knee osteoarthritis[4, 5]. By adjusting the mechanical axis of the knee joint, this operation reduces the load on one side of the knee joint, to reduce the unilateral knee joint pain and improve the symptoms of knee osteoarthritis[4].

Based on computer-assisted surgery-related technologies and the inadequacies of traditional surgery, this study developed an exclusive preoperative planning system for high tibial osteotomy and designed and manufactured patient-specific instrument according to the planning to achieve the goal of surgical correction.

[1] Wieland, H. A., Michaelis, M., Kirschbaum, B. J., & Rudolphi, K. A.. Osteoarthritis - an untreatable disease?. Nature reviews. Drug discovery, 4(4), 331–344 (2005).
[2] Shane Anderson, A., & Loeser, R. F.. Why is osteoarthritis an age-related disease?. Best practice & research. Clinical rheumatology, 24(1), 15–26(2010).
[3] Pereira, D., Ramos, E., & Branco, J.. Osteoarthritis. Acta medica portuguesa, 28(1), 99–106(2015).
[4] Prodromos, C. C., Amendola, A., & Jakob, R. P.. High tibial osteotomy: indications, techniques, and postoperative management. Instructional course lectures, 64, 555–565(2015).
[5] Liu, X., Chen, Z., Gao, Y., Zhang, J., & Jin, Z.. High Tibial Osteotomy: Review of Techniques and Biomechanics. Journal of healthcare engineering, vol. 2019, 8363128(2019)

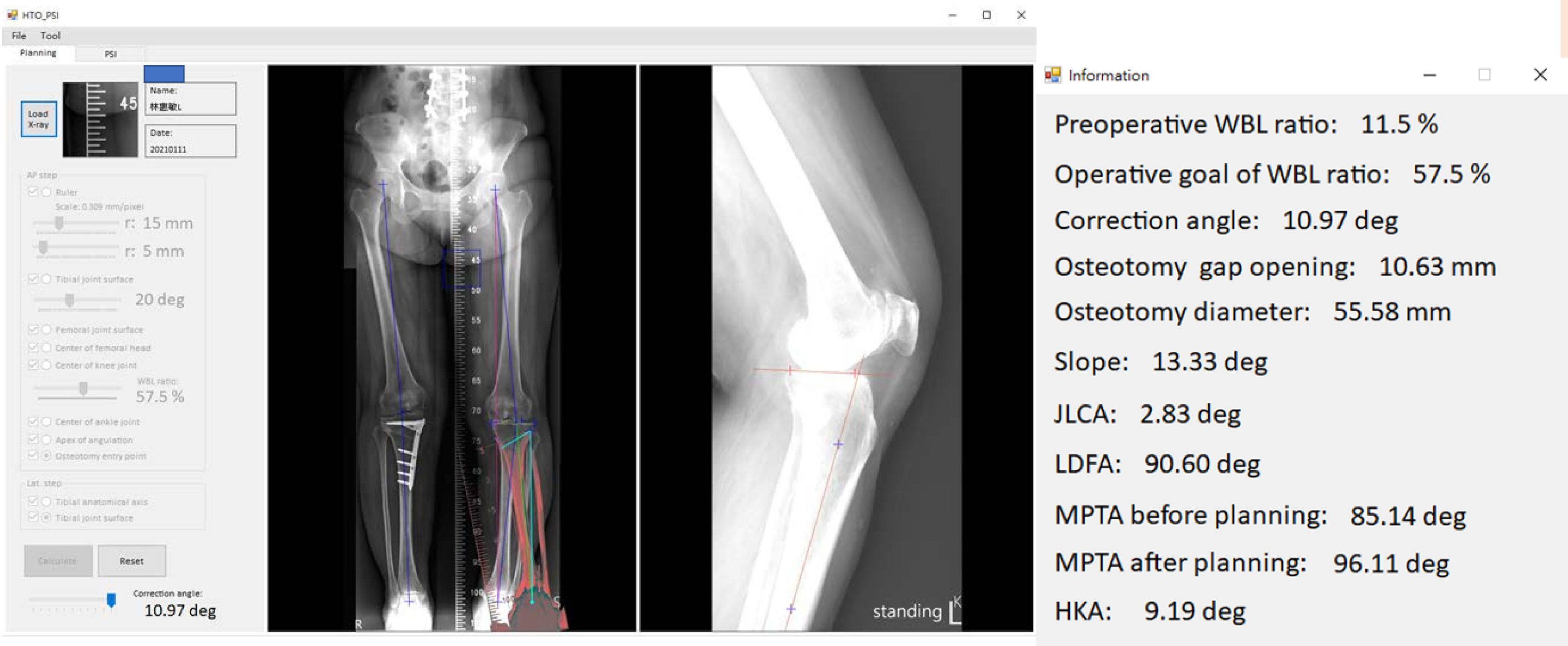
## Method

### Planning Software Development

X-ray images can show the medial and lateral weight bearing of the knee joint on the AP view. Thus, X-ray images can be used for preliminary 2D osteotomy planning.

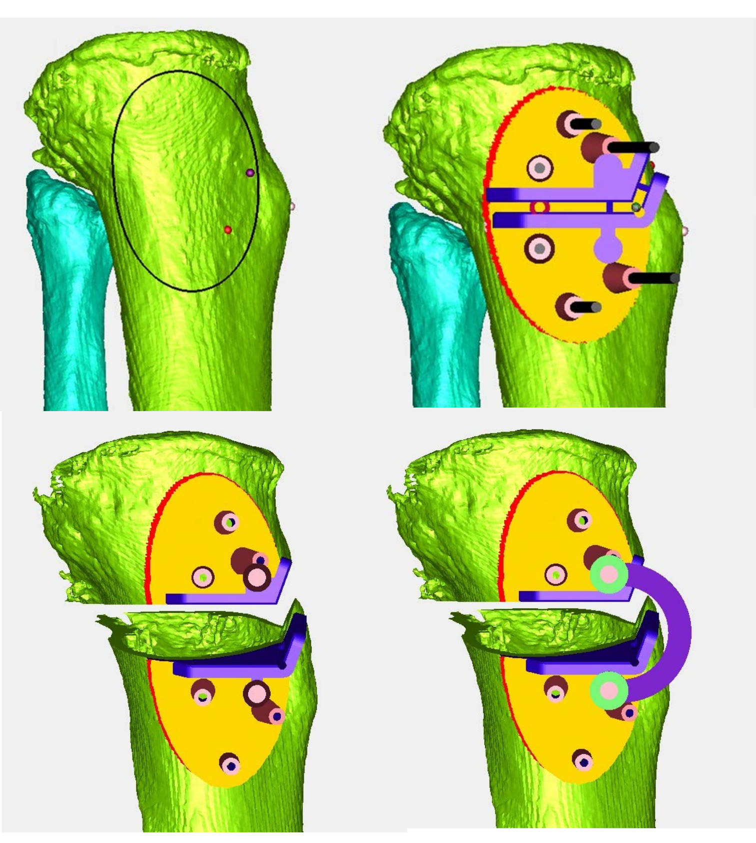
After conducting the inter-dimension tibial feature superimposition, the conversion relationship between the coordinate systems was established, an inter-dimension conversion matrix was obtained, and X-ray osteotomy planning feature information was transferred to 3D.

We illustrate preoperative WBL ratio and its operative goal in the software. We also provide correction angle, osteotomy gap opening and diameter, slope, JLCA, LDFA, MPTA before and after planning, HKA in the planning software.

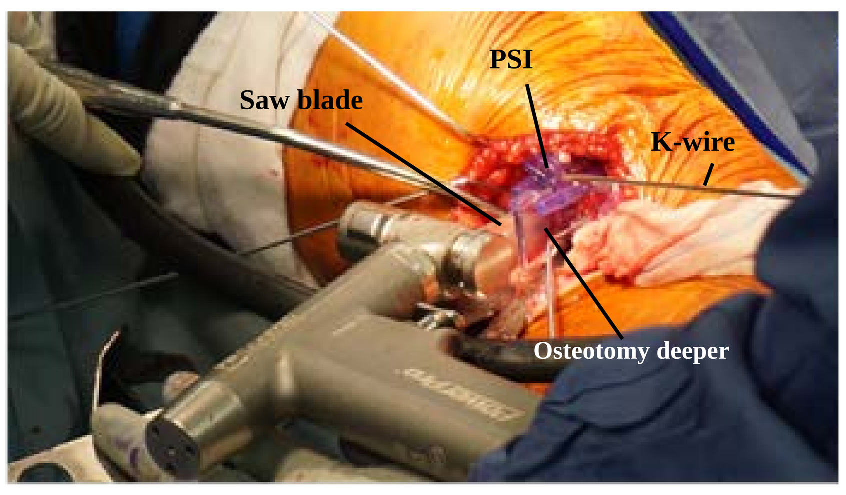



### Patient Specific Instrument

The pre-printed tibial model and the osteotomy guide instrument are used to simulate the fitting position. After determining the position, the base of the PSI is fit to the osteotomy site of the patient's medial tibia, and the K-wire is inserted into the fixation holes. After fixing the PSI on the tibia, the K-wire is inserted into the detection hole, and an X-ray photograph is taken to confirm the osteotomy depth. After the osteotomy is completed, the tibial osteotomy area is spread until the semicircular fastener can be buckled into the two spreading pyramids, indicating that the preoperative planned correction angle has been reached. The PSI is removed, and the osteotomy area with a bone plate is fixed. The wedge-shaped bone filler is cut to an appropriate size and placed into the osteotomy area. Finally, the incision is sutured, and the operation is completed.



We applied the guiding device on clinical trial cases and analyzed the changes of the knee joint mechanical axis pre-surgery and 3, 6, 12 months post-surgery.

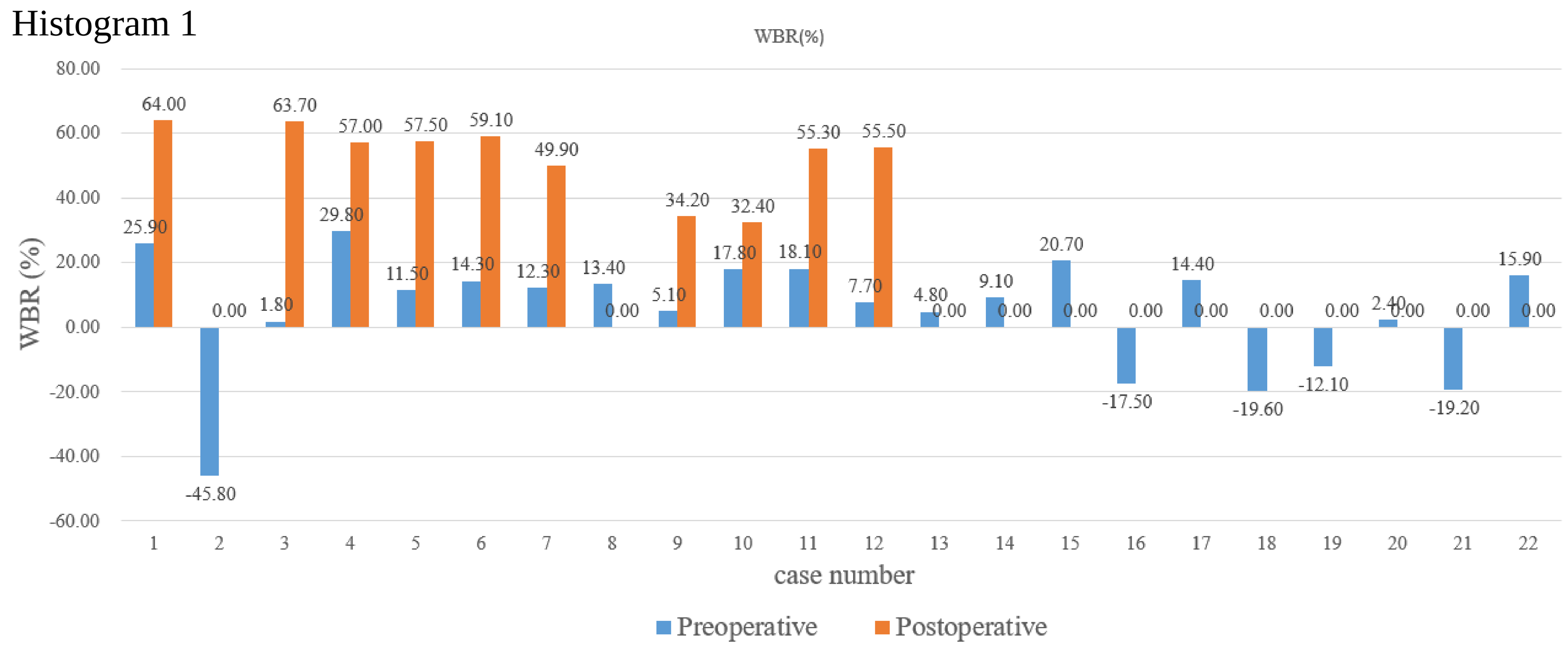



## Result

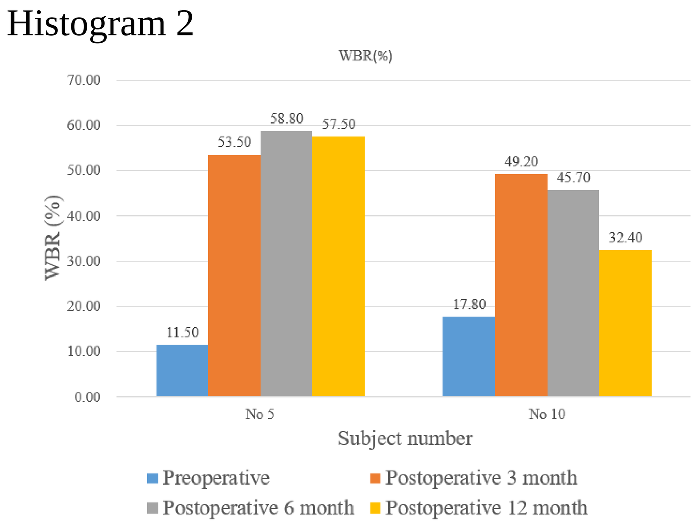
For all cases, the average difference in the preoperative planning central axis matching angle was 6.58 $\times 10^{-5}$ degrees, the average operation time was 2 h and 13 min, and the average number of X-ray images was about 25. Compared with the planned target, the average difference was -0.05±4.91° in Wedge angle, -2.89±10.41% in WBR and 0.66±2.25° in HKA at 12 months after surgery. At 12 months after surgery, the average WBR was 52.86±10.52%, HKA was -0.63±2.27°, and OKS was 42.67.

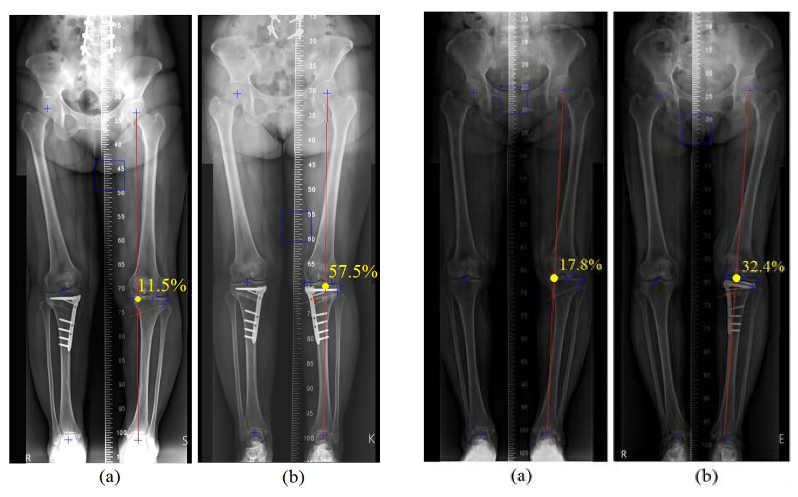
Histogram 1 shows the preoperative and postoperative WBRs for all cases. Histogram 2 shows the preoperative and postoperative WBRs at 3, 6, and 12 months in cases 5 and 10. Figures below show the preoperative and postoperative WBRs in two cases at 12 months, respectively.

Histogram 1




Histogram 2




## Discussion & Conclusions

The operative times with and without the use of osteotomy guides in previous related studies were compared. No significant improvement in the operative time was found when osteotomy guides were used. It is speculated that the operative time is related to the way of surgery among different surgeons. Although the use of PSI can reduce the number of X-ray images taken to confirm the surgical target, physicians need time to familiarize themselves with the use of PSI in surgery. Furthermore, the surgical procedure is relatively simple, which means that it is difficult to significantly shorten the operation time.

In this study, a computer-aided high tibial osteotomy planning system was developed. The preoperative two-dimensional osteotomy planning was performed using the standing X-ray images of the patient's lower limbs, and then the transfer relationship between the two-dimensional and three-dimensional planning was established, and the osteotomy was performed in three dimensions. Under the same system process, users can design patient-specific instrument that meet clinical needs for different patients. It is composed of pre-designed model accessories and planning feature information to achieve preoperative planning goals and reduce manual repetitive design. This way reduce manual repetitive design steps and time, and the amount of radiation for doctors and patients during surgery.