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Distal tibial tubercle-high tibial osteotomy with assistance of modifiable spreader in the treatment of varus knee osteoarthritis

A retrospective observational study

Qiang Fu, MD[a], Shijie Yan, MD[a], Xizhi Hou, MD[a], Zeyang He, MD[a,*], Quanxiu Lu, MD[a], Weijie Yuan, MD[a], Hongliang Hu, MD[b]

Abstract

As one of the knee preservation surgical approaches, good clinical outcomes of high tibial osteotomy were reported. Aims of this study were to analyze the clinical outcome and pre- and postoperative radiographical parameter and knee functional score between distal tibial tubercle high tibial osteotomy (DTTHTO) and open wedge- high tibial osteotomy (OWHTO) in patients with varus knee osteoarthritis after more than 1 year following-up. A total of 194 consecutive patients in our joint center from March 2016 to October 2021 were enrolled, according to the surgical method, patients were divided into DDTHTO and OWHTO groups. Radiographic parameters of Kellgren-Lawrence grading, hip-knee-ankle angle, weight bearing line ratio and medial tibial plateau angle, knee functional score of American knee society (AKS) score, western Ontario and McMaster universities arthritis index (WOMAC) score, visual analogue score (VAS) were introduced to evaluate clinical outcome for patients who received DDTHTO and OWHTO. There were 103 knees and 89 knees in the OWHTO and DTTHTO group, respectively. Mean weight bearing line ratio for OWHTO and DTTHTO were 25.1 ± 11.7 and 25.2 ± 12.0% respectively, medial tibial plateau angle and hip-knee-ankle angle angle demonstrated that all patients in the present study inherited a varus angle ranges from 3.4° to 9.5°. Preoperative AKS, WOMAC and VAS were 68.4 ± 5.7 versus 69.0 ± 5.9, 109.3 ± 15.0 versus 107.7 ± 14.0 and 6.8 ± 1.0 versus 6.9 ± 0.8, and there was no significant difference between 2 groups ($P > .05$). Mean postoperative AKS and WOMAC score for patients in both OWHTO and DTTHTO group were significantly improved, moreover, postoperative VAS of DTTHTO patients was lower than that in OWHTO group ($P < .05$). When comparing the operation time, intraoperative blood loss and bone union time, DHHTO group shows a superiority in these variables over patients in OWHTO (121 ± 29.6 vs 145.7 ± 35.2 minutes, 115.0 ± 20.8 vs 103.3 ± 17.3 mL, 13.7 ± 4.1 vs 12.0 ± 2.8 weeks; $P < .005$) and incidence of complication was lower for DTTHTO group. DTTHTO in patients with varus knee osteoarthritis has good clinical outcomes, and it can achieve a better postoperative alignment. Operation time and surgical trauma were also less in patients who underwent DTTHTO.

Abbreviations: AKS = American knee society, DTTHTO = distal tibial tubercle high tibial osteotomy, HTO = high tibial osteotomy, K-L = Kellgren-Lawrence, KOA = knee osteoarthritis, MPTA = medial tibial plateau angle, OWHTO = open wedge high tibial osteotomy, TKA = total knee arthroplasty, VAS = visual analogue score, WBL = weight bearing line ratio, WOMAC = western Ontario and McMaster universities arthritis index.

Keywords: AKS, bone union, DTTHTO, high tibial osteotomy, OWHTO, patella baja

1. Introduction

Knee osteoarthritis (KOA) is a degenerative disease that significantly compromised the quality of life of geriatric people. Osteoarthritis affected approximately 10% of men and 18% of women worldwide in 2015, causing a huge economic burden to patients, families and even the society. The normal knee joint has an anatomical valgus angle of 5° to 8°,[1] therefore, 60% to 75% and 25% to 40% weight load passes through the medial and lateral compartmental of knee joint, respectively. Owing to these somatological characteristics, KOA mainly involves the medial or anteromedial compartment of knee.

An epidemiological investigation which focused on aged Chinese population showed the incidence of KOA was 8.1%

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] Department of Orthopedic Surgery, The Third Hospital of Shijiazhuang, Shijiazhuang, Hebei, P.R. China, [b] Department of Radiology and Nuclear Medicine, The First Hospital of Hebei Medical University, Shijiazhuang, Hebei, P.R. China.

** Correspondence: Zeyang He, Department of Orthopedic Surgery, The Third Hospital of Shijiazhuang, No. 15 South Tiyu Street, Shijiazhuang 050011, Hebei Province, P.R. China (e-mail: hzyssy0930@126.com).*

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in people older than 65 years, considering a huge population in China, there were a large number of persons who suffered with KOA. Although total knee arthroplasty (TKA) was demonstrated to inherit a good survival-ship and excellent knee functional status, many young patients (< 65 years) underwent TKA too early, when they received an ineffective or unsatisfactory clinical outcome of rehabilitation exercises, analgesic treatment of nonsteroidal anti-inflammatory drugs, hyaluronic acid and platelet-rich plasma injection and knee arthroscopic debridement surgery.

High tibial osteotomy (HTO) was first introduced by Jackson[2] and his colleagues in 1961 with the aim to transfer the lower extremities' force line from medial to lateral compartment and to relieve clinical symptoms of KOA. As one of the knee preservation surgical approaches, satisfactory clinical outcomes of HTO were reported by scholars.[3–5] Surgical technology and auxiliary instruments have been constantly improved by orthopedic surgeons, presently; open wedge high tibial osteotomy (OWHTO) with the advantages of limited surgical trauma and ideal alignment control has become the most popular surgical method. However, the operation procedures of OWHTO are still complicated, which leads to a long learning curve. In addition, the stable placement of osteotomy spreader is critical to acquire a satisfying lower limb force line after surgery. Moreover, sometimes, the spreader would inevitably affect the rational placement of internal fixation, which would accompany by the loss of osteotomy angle and splitter height.

In clinical practices, we adopted the surgical approach of distal tibial tubercle high tibial osteotomy (DTTHTO) during operation, and we have designed a new modified spreader to facilitate the application of surgery. Aims of this study were to analyze the clinical outcomes and pre- and postoperative radiographical variables between DTTHTO and OWHTO in patients with varus KOA after more than a 1 year follow-up period and to demonstrate the advantages and disadvantages of the new designed spreader.

2. Patients and methods

2.1. Study subjects

This study was approved by the Institutional Review Board of our hospital and was designed in accordance with the principles outlined in the Declaration of Helsinki and received written consent from all the study participants. This study retrospectively enrolled 194 consecutive patients in our joint center from March 2016 to October 2021, data from electronic medical records and picture archiving and communication system of these patients were recruited and reviewed.

The inclusion criteria were: patients aged ≤ 65 years old; patients with an acceptable physical condition and without absolute contraindications; the surgical knee was graded ≤ III according to Kellgren-Lawrence (K-L) classification system; patients who had no neuromuscular disease and myodynamia of lower limbs grade ≥ IV; varus deformity of the knee < 15 °, and flexion contracture deformity < 10 °; medial proximal tibial angle (MPTA) < 85 °.

The exclusion criteria were: K-L classified ≥ IV; the knee joint showed poor stability on physical examination; compression fracture of medical tibial plateau due to severe osteoporosis or prior trauma; femoral patellar arthritis, rheumatoid arthritis, gouty arthritis, inflammatory arthropathy and other musculoskeletal diseases; knee varus caused by self-development factors such as femoral trochlea or femoral condyle.

2.2. Surgical method and rehabilitation

1.2.2. OWHTO group. A longitudinal incision 5 to 6 centimeters was adopted on the medial side of the proximal tibia to expose the medial side of the tibial plateau and a part of medial collateral ligament. Two Kirschner wires were placed towards the tip of fibula head to guide the horizontal and direction of osteotomy under fluoroscopy and below medical tibial plateau. The aimed osteotomy angle was calculated by the weight-bearing full-length X-ray, and the Miniaci method was used to determine the exact opened height. Osteotomy was undergone under the guide pin, so as to prevent the osteotomy line from extending to the articular surface. The osteotomy was stopped when the line was 1 centimeter away from the lateral cortex, meanwhile, superior oblique osteotomy was performed at 110° above the tibial tubercle. The osteotome is placed at the osteotomy site and the osteotomy gap is opened, the lateral tibial cortex is completely retained as the hinge of bone. And the weight-bearing line should pass through Fujisawa point.

2.2.2. DTTHTO group. A 4 to 6 centimeters longitudinal incision was made at the upper edge of pes anserinus, 2.5 centimeters below the joint line (Fig. 1). The osteotomy line passes lower 1/3 of tibial tubercle and 0.5 centimeter below the superior tibiofibular joint which forms a 30° angle to the joint line (Fig. 2). Two Kirschner wires were drilled in parallel along the osteotomy line, and oblique osteotomy was performed along the Kirschner wires until it was about 10mm away from the front of the tibial tubercle and the lateral cortex of the tibia, the bone hinge was fully reserved. Kirschner wire of 3.5mm was used to drill 5 holes from different direction to disperse the stress of the contralateral cortex. The osteotomy gap was gradually extended with the spreader which we designed (Fig. 3) until the line of femoral condyles formed a 93° angle with the central axis of the fibula. TomoFix plate was used for both HTO patients in the 2 groups (Fig. 4).

Isometric quadriceps exercises, active ankle pumping, and straight leg-raising exercises were encouraged on the first day after operation. Generally, the drain and compressive dressing were removed on the second day after surgery, and longest drainage time would not be more than 3 days. Patients were allowed to flex and extend the knee joint as much as tolerated when lying in bed and without weight bearing. Partial weight bearing was permitted for the next 2 weeks, and full weight bearing was permitted beginning 4 weeks after the operation.

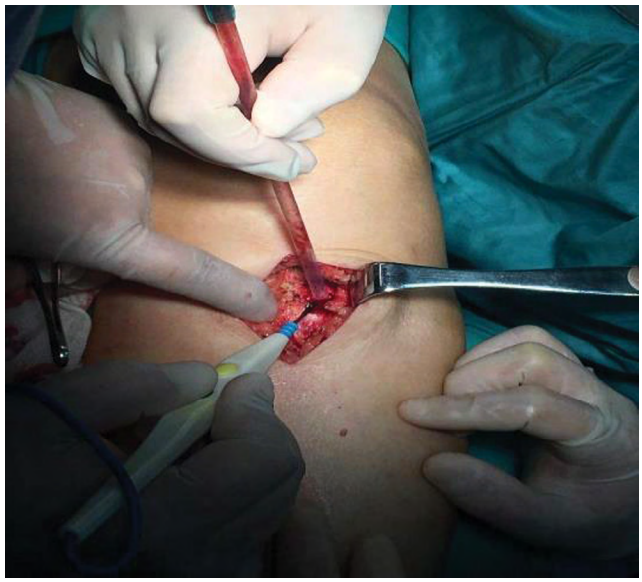

Figure 1. Incision of DTTHTO method. DTTHTO = distal tibial tubercle high tibial osteotomy.

3.2.2. Radiological and clinical evaluation. For radiographic evaluation, the preoperative and postoperative degree of osteoarthritis was classified by K-L grading. Hip-knee-ankle angle, weight bearing line ratio (WBL) and MPTA were introduced preoperative and at final follow-up to demonstrate the weight-bearing line and anatomical characteristics. Loss of correction angle was calculated by the change of WBL and bone union time was assessed by the criteria which formulated by Apley and Solomon.[6] Functional status of the surgical knee was quantified by American knee society (AKS) score and western Ontario and McMaster universities arthritis index (WOMAC) score, and perioperative pain of the knee joint was evaluated by visual analogue score (VAS). We also extracted variables such as operation time (minutes) and intraoperative blood loss (mL) to demonstrate the differences between the 2 surgical methods.

2.3. Statistical analysis

Quantitative variables were described as mean ± SD and qualitative variables were expressed with frequencies. Whitney U-test was carried out for abnormally distributed continuous variables and *t* test for normally distributed variables between DTTHTO and OWHTO groups. $P < .05$ was considered to be indicative of statistical significance. All statistical procedures were performed by SPSS 20.0 software package (SPSS Inc., Chicago, Illinois).

3. Results

A total of 216 knees of 194 patients were reviewed, 2 patients have undergone TKA and 5 received unicompartmental knee arthroplasty, and 9 patients were lost at follow up. Finally, 178 patients with 192 knees were enrolled in this study.

There were 103 knees and 89 knees in the OWHTO and DTTHTO group, respectively. Table 1 shows the demographic data for all patients. There were 81 and 75 female patients in these 2 groups, respectively. The mean body mass index for patients in OWHTO group was 25.7 kg/m^2 and which was similar to that of DTTHO group (26.0 kg/m^2); therefore, according to the Chinese criteria, the majority of patients were overweight. The most common accompanying comorbidities were hypertension, diabetes mellitus and coronary heart disease for the recruited patients. Moreover, according to the baseline data demonstrated in Table 1, there was no significant difference for these variables between the 2 group ($P > .05$).

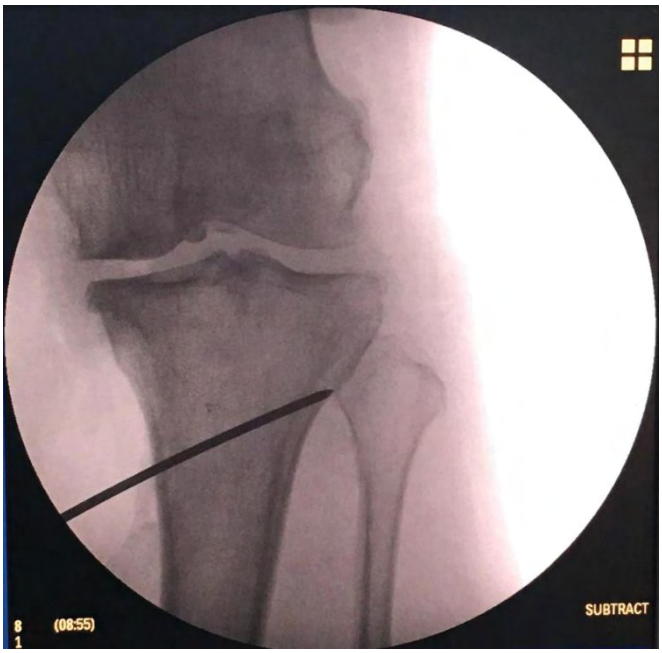

Figure 2. The primal direction of osteotomy for DTTHTO procedure. DTTHTO = distal tibial tubercle high tibial osteotomy.

Preoperative radiographic parameters of all patients were summarized in Table 2. There were 60 and 24 patients in OWHTO group and 58 and 19 patients in DTTHTO group grade K-L II and III. Mean WBL for OWHTO and DTTHTO were 25.1 ± 11.7 and 25.2 ± 12.0%, respectively. What is more, the MPTA and hip-knee-ankle angle angle demonstrated that all patients in the present study inherited a varus angle ranges from 3.4° to 9.5°. Preoperative AKS, WOMAC and VAS were 68.4 ± 5.7 versus 69.0 ± 5.9, 109.3 ± 15.0 versus 107.7 ± 14.0 and 6.8 ± 1.0 versus 6.9 ± 0.8, as for all these variables mentioned above, no significant differences were founded in the statistical process ($P > .05$, Table 2).

After 2.6 ± 1.5 and 2.5 ± 1.0 years follow-up for the 2 groups, the mean postoperative AKS and WOMAC score for patients in both OWHTO and DTTHTO group were significantly improved. Moreover, postoperative VAS of DTTHTO patients was lower than that in OWHTO group ($P < .05$, Table 3). When comparing the operation time, intraoperative blood loss and bone union time, DHHTO group shows a superiority in these variables over patients in OWHTO (121 ± 29.6 vs 145.7 ± 35.2 minutes, 103.3 ± 17.3 vs 115.0 ± 20.8 mL, 12.0 ± 2.8 vs 13.7 ± 4.1 weeks; $P < .005$). There were 2 patients who were diagnosed with superficial surgical site infection (SSI) in OWHTO group; 11 and 2 patients in OWHTO and DTTHO group had experienced postoperative deep venous thrombosis (DVT) which indicated an incidence of 11.8% and 2.3%, respectively.

4. Discussion

At present, attention has been paid to the concept and surgical methods of knee preservation, the ideal treatment is to relieve KOA with minimally invasive means and without disequilibrating the biological activity and physiological characteristics of soft tissues around the knee joint. As one of the traditional knee preservation surgeries, HTO can preserve the function of knee joint to the maximum extent. The purpose of HTO is to change the lower limb force line by osteotomy, restore varus status of the knee to valgus to some extent and reduce the pressure of the medial compartment of the knee joint, relieve the patient's symptoms, repair the cartilage and avoid its further destruction, therefore, to delay or even avoid TKA.[7] OWHTO reserves bone mass for TKA which may needed in the future; however, some cases of bone delayed healing or nonunion were founded in patients who underwent OWHTO.[8–10]

Considering the above circumstances and with the aim to improve clinical outcome of HTO, 89 and 103 knees of DTTHTO and OWHTO were demonstrated and analyzed in term of preoperative radiographic parameters, knee functional status and other related variables. In addition, in order to facilitate intraoperative operation and control the height of osteotomy gap and alignment of lower extremity, we designed and applied a mew spreader during operation. The follow-up data showed that both DTTHTO and OWHTO could achieve better clinical results and DTTHO technique also possess the advantages of shorter operation time, less blood loss and a rapid bone union.

During OWHTO, we performed osteotomy in the level above tibial tuberosity, at the same time an upward osteotomy was also proceeded behind the tibial tubercle. Finally, a wedge gap was formed after extension and autogenous or allogeneic bone grafting were transplant and internal fixator were implanted.

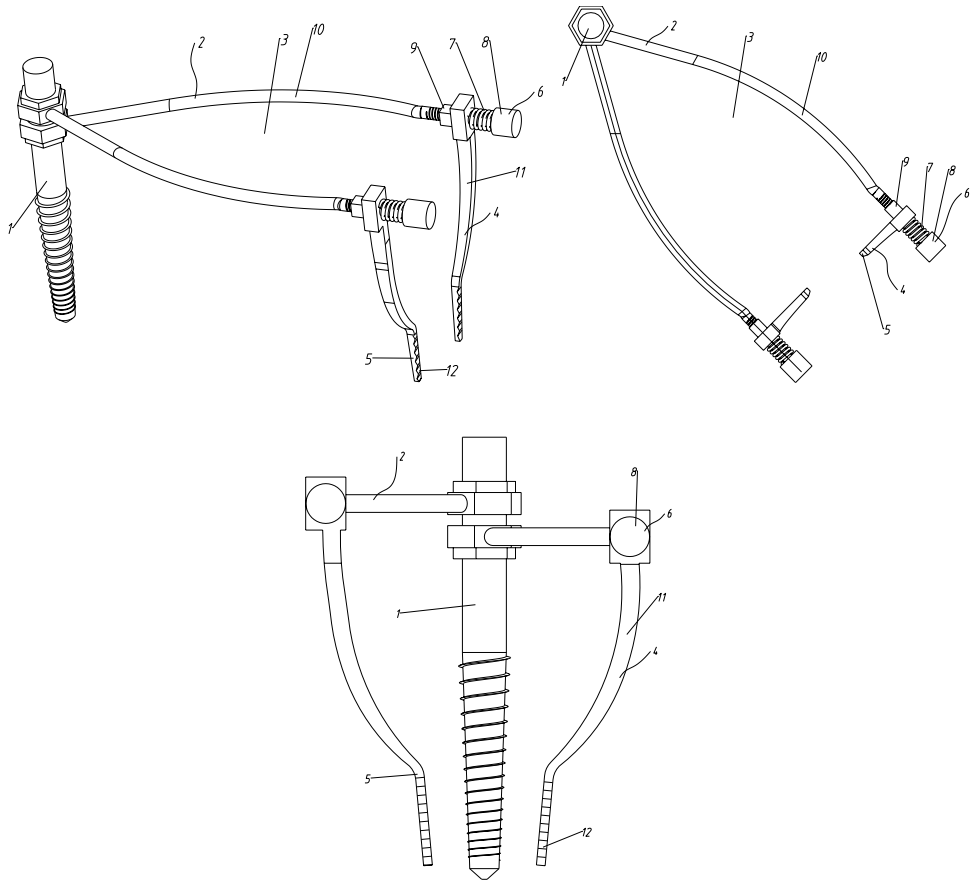

Figure 3. The diagram of biplane modifiable tibial spreader.

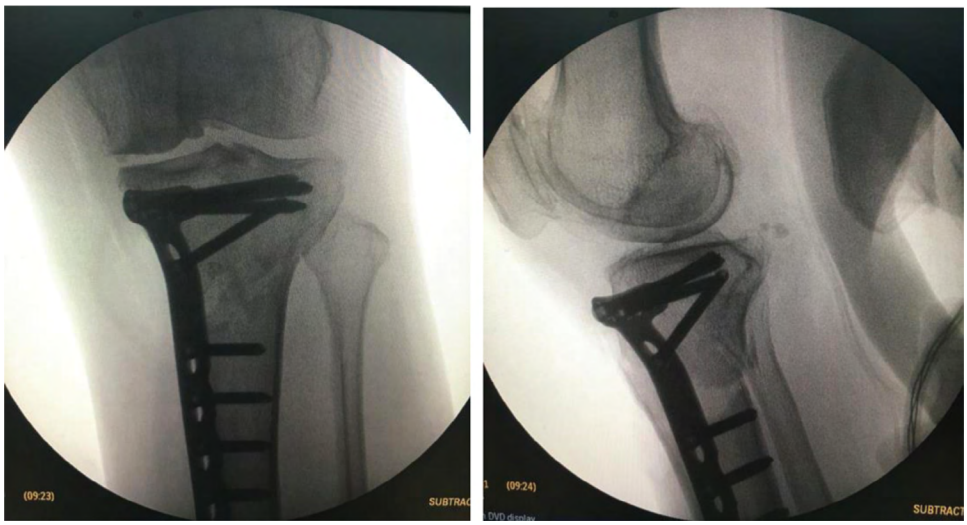

Figure 4. Postoperative anteroposterior view of knee joint showed satisfactory position of internal fixation.

The blood supply in this region is abundant and the bone contact area after osteotomy is also larger than that in DTTHTO, which is conducive to bone growth; however, incidence of delayed or nonunion was still higher than distal tibial tubercle-HTO. Another serious complication after OWHTO was the change of position of patella,[11–13] which was caused by the transform of anatomical characteristics of proximal tibia. Moreover, contraction of patellar ligament after scar formation would inevitably exacerbate this condition. The alignment and pressure of femoral patellar joint would change once patella baja occurred, and patients may complain of anterior knee pain, limited range of motion even patellofemoral arthritis. Although some scholars have indicated that patella baja does not affect the clinical outcome of HTO,[14] these results may complicate the implementation of surgery for patients who must undergo TKA in the future.

Osteotomy of DTTHTO was performed under the level of tibial tubercle, this procedure could not only avoid the injury

Table 1

Basic demographic data of patients in OWHTO and DTTHTO group.

Variables	OWHTO (93 patients; 103 knees)	DTTHTO (85 patients; 89 knees)	*P*
Age (yr)	65.3 ± 4.9	66.1 ± 5.3	n.s.
Gender (male/female)	12/81	10/75	n.s.
BMI (kg/m^2)	25.7 ± 2.0	26.0 ± 2.4	n.s.
Duration of present illness (yr)	6.3 ± 3.5	6.0 ± 3.1	
Comorbidity			n.s.
hypertension	27	20	
diabetes mellitus	6	4	
coronary heart disease	3	1	
Tobacco consumption	10	7	n.s.
Alcohol drinking	14	11	n.s.

BMI, Body mass index, underweight, DTTHTO = distal tibial tubercle high tibial osteotomy, OWHTO = open wedge high tibial osteotomy.
<18.5; normal, 18.5-23.9; overweight, 24-27.9; obesity, 28-31.9; morbid obesity, 32 and more.
n.s. *P* > .05.

Table 2

Preoperative radiographic parameters and knee functional status of patients in the present study.

Variables	OWHTO (93 patients; 103 knees)	DTTHTO (85 patients; 89 knees)	*P*
K-L			n.s.
I	9	8	
II	60	58	
III	24	19	
WBL (%)	25.1 ± 11.7	25.2 ± 12.0	n.s.
MPTA (°)	84.9 ± 2.3	85.3 ± 2.7	n.s.
HKA (°)	-6.4 ± 3.1	-6.3 ± 2.9	n.s.
AKS	68.4 ± 5.7	69.0 ± 5.9	n.s
WOMAC	109.3 ± 15.0	107.7 ± 14.0	n.s
VAS	6.8 ± 1.0	6.9 ± 0.8	n.s

DTTHTO = distal tibial tubercle high tibial osteotomy, HKA = hip-knee-ankle angle, K-L = kellgren-lawrence, OWHTO = open wedge high tibial osteotomy, VAS = visual analogue score, WBL = weight bearing line ratio, WOMAC = western Ontario and McMaster universities arthritis index.
"-" varus, n.s. *P* > .05.

to metaphyseal but also reserve the integrality of tibial tubercle; therefore, position of patella would not change after DTTHTO. It is certain that, DTTHTO has itself disadvantages, the most common 1 was fracture of tibial tubercle. In our study, we have drilled 5 holes on the contralateral cortex of tibia, which will weaken the stress of cortical bone and reduce the incidence of hinge and tibial tubercle fracture, subsequently ensuring a relatively rapid bone union.

Owing to the fewer osteotomy procedures, patients in DTTHTO group have a shorter operation time and intraoperative blood loss. Similarly, less surgical steps will accompany by less damage to soft tissues around the knee joint, and fewer surgical trauma along with faster bone union leading to a lower VAS score for DTTHTO group at early postoperative period and final follow-up when compared with patients in OWHTO group. Although there was no significant difference, postoperative radiographic data showed the mean MPTA of DTTHTO group was larger than that of OWHTO, and we hypothesized that character of single plane osteotomy of DTTHTO and the stability provided by the newly designed spreader were beneficial to the less loss of correction angle.

There were some limitations for the present study. First, as a retrospective study, the included samples inevitably have selective bias, and the sample size is still relatively small. Secondly, the regeneration of medial compartment cartilage and the regression of lateral compartment cartilage are important indicators for this investigation; however, some patients have not had their internal implant removed until last follow-up, therefore the status of cartilage could not be assessed under the arthroscope; Thirdly, the follow-up time was short, and the medium and long-term clinical outcomes of DTTHTO and OWHTO were not evaluated.

Table 3

Comparison of postoperative radiographic parameters, knee functional score and intraoperative variable between the 2 groups.

Variables	OWHTO (n = 103)	DTTHTO (n = 89)
WBL (%)	58.3 ± 12.6	57.9 ± 9.1§
MPTA (°)	90.7 ± 2.5	91.2 ± 3.0§
HKA (°)	4.3 ± 1.0	4.5 ± 1.7§
AKS	85.0 ± 4.4	84.8 ± 3.9§
WOMAC	52.6 ± 12.7	51.1 ± 11.5§
VAS	3.1 ± 0.9	2.2 ± 0.2*
Operation time (min)	145.7 ± 35.2	121 ± 29.6*
Blood loss (mL)	115.0 ± 20.8	103.3 ± 17.3*
Bone union time (w)	13.7 ± 4.1	12.0 ± 2.8*
Postoperative complication		
SSI	2	0§
DVT	11	2*

AKS = American knee society, DTTHTO = distal tibial tubercle high tibial osteotomy, HKA = hip-knee-ankle angle, MPTA = medial tibial plateau angle, OWHTO = open wedge high tibial osteotomy, VAS = visual analogue score, WBL = weight bearing line ratio, WOMAC = western Ontario and McMaster universities arthritis index.
* *P* < .05,
§ *P* > .05.

5. Conclusion

DTTHTO in patients with varus KOA has good clinical outcomes and short-term survivorship. With the assistance of a newly designed osteotomy spreader, DTTHTO can achieve a better postoperative alignment of low limb, operation time and surgical trauma were also less in patients underwent DTTHTO.

Author contributions

Conceptualization: Zeyang He.
Data curation: Qiang Fu, Shijie Yan, Xizhi Hou, Hongliang Hu.
Formal analysis: Shijie Yan, Xizhi Hou, Weijie Yuan.
Investigation: Qiang Fu, Xiuquan Lu.
Methodology: Hongliang Hu.
Resources: Weijie Yuan.
Software: Xiuquan Lu.
Writing – original draft: Zeyang He.
Writing – review & editing: Zeyang He.

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