Clinical Results Associated with Changes in Posterior Tibial Slope Following Open-Wedge High Tibial Osteotomy

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Abstract:

Background: The primary target of opening-wedge high tibial osteotomy (OWHTO) is to the coronal plane is to correct the coronal malalignment. However, other geometric knee parameters are affected as well, including the posterior tibial slope (PTS).

Objectives: The main objective of this prospective study is to investigate whether there was a significant correlation between the PTS change and patients' clinical outcomes following OWHTO.

Patients and Methods: Twenty knees with symptomatic isolated medial compartment knee osteoarthritis and varus deformity undergoing OWHTO were evaluated. Clinical evaluation was performed according to the Knee Society Score (KSS). Radiographic evaluation was made according to the changes in the PTS. The correlation between changes in PTS and KSS was assessed by the Pearson test.

Results: The mean follow-up period was 8.4 ± 1.6 months. The average KSS showed significant improvement from 96 ± 18 preoperatively to 172 ± 13 at last follow-up ($P< .05$). The PTS increased from 9.9 ± 2.6° preoperatively to 12 ± 2.8° at the last follow-up ($P< .05$). No correlation was found between changes in PTS and improvement in knee scores.

Conclusion: This study showed a significant increase in PTS following OWHTO. However, this increase was not associated with worse clinical outcomes.

Keywords: Osteoarthritis, Opening-wedge, High tibial osteotomy, Posterior tibial slope.

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Introduction

Knee osteoarthritis (OA) is a degenerative process characterized by progressive loss of articular cartilage. Surgical treatment is indicated in moderate to severe cases with failed conservative therapy. Total knee arthroplasty (TKA) has been the most effective surgical treatment modalityin advanced OA. However, other treatment options such as high tibial osteotomy (HTO) have achieved favourable outcomes with appropriate patient selection and meticulous preoperative planning in medial compartment arthrosis with varus deformity **(Insall et al., 1984; Yasuda et al., 1992)**.

HTO shifts the weight-bearing axis from the damaged medial compartment to the relatively unaffected lateral compartment, which alleviates the pain and slows down the degenerative process **(Agneskirchner et al., 2004)**. The two most performed procedures are: closed-wedge high tibial osteotomy (CWHTO) and open-wedge high tibial osteotomy (OWHTO).

OWHTO has become increasingly popular owing to its advantages, including easier alignment correction and avoidance of serious complications, such as peroneal palsy **(Han et al., 2013)**. Correction of the coronal plane is the surgeon's primary target. Nevertheless, other geometric aspects of the knee joint are also affected, such as the posterior tibial slope (PTS) **(Schubert et al., 2020)**. Nha et al. concluded that OWHTO increases the PTS by an average of 2.02° **(Nha et al., 2016)**. Changes in the PTS tend to influence patellar height, cruciate ligaments' biomechanics, and future TKA.

Few reports in the literature discussed the effect of PTS changes after OWHTO on patients' functional results **(Dragosloveanu et al., 2014; Ozel et al., 2017)**. Therefore, this study was conducted to investigate whether there is a significant correlation between the PTS change and patients' clinical outcomes.

Patients and methods

A prospective case series was conducted to evaluate patients undergoing OWHTO at Qena University Hospital. Informed consent was obtained from all participants. The study was approved by the Research Ethics Committee of our institution (Approval code: 252).

Patients were eligible for OWHTO if conservative treatment failed with symptomatic medial compartment knee OA stage I or II according to Ahlbäck classification(**Fig.1**)**(Hangaard et al., 2022)**, with varus malalignment. Patients were excluded ifthey met any of the following exclusion criteria:

- Age older than 70 years.
- Morbid obesity (BMI more than 40 Kg/m^2).
- Symptomatic lateral and/or patellofemoral arthritic changes.
- Fixed flexion deformity > 15 degrees.
- Flexion range of motion less than 90 degrees.
- Severe varus deformity more than 20 degrees.

Surgical Technique

Preoperative planning was conducted using a method previously described by **(Miniaci et al., 1989)**(**Fig.2**).

1. A line (W1) is drawn connecting the centre of the femoral head and the

centre of the talar dome representing the preoperative Mikulicz line.

2. Determine the Fujisawa point (FP) 62.5% from the medial border along the longest medial-to-lateral width of the tibial plateau (just lateral to the lateral tibial eminence).

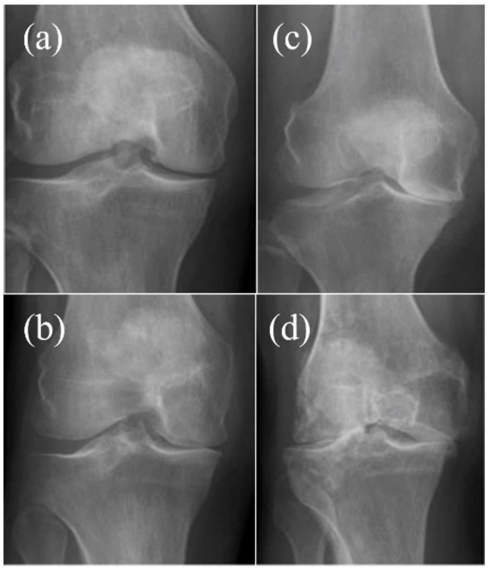

Fig.1. Ahlbäck classification.
(a) grade I, (b) grade II, (c) grade III, (d) grade IV.

3. A line (W1) is drawn connecting the centre of the femoral head and the centre of the talar dome representing the preoperative Mikulicz line.

4. Determine the Fujisawa point (FP) 62.5% from the medial border along the longest medial-to-lateral width of the tibial plateau (just lateral to the lateral tibial eminence).

5. Another line (W2) is projected from the center of the femoral head, passing through the Fujisawa point, and extrapolated to the level of the talar dome as the post-operative ankle center representing the postoperative Mikulicz line.

6. The osteotomy hinge point (HP) was then determined 15 mm inferior to the lateral tibial plateau and 10 mm medial to the PTFJ.

7. A line (A1) is drawn connecting the HP and the center of the preoperative ankle joint and a line (A2) connecting the HP and the center of the postoperative ankle joint.

8. An angle between lines (A1) and (A2) was annotated with the apex at the selected HP and recorded as the correction angle (α).

9. A predicted osteotomy line (O1) is then drawn arising above the pes anserinus 40 mm inferior to the medial border of the tibial plateau projecting towards the hinge point. The obliquity of this plane was determined to be 110° from a vertical line passing above the HP.

10. A predicted opening line (O2) was drawn from Line (O) at the predetermined correction angle (α). The base (WB) of the formed triangle formed was measured as the predicted opening wedge gap.

We adopted basic surgical steps described by previous authors **(Hernigou et al., 1987; Hernigou and Ma, 2001; Franco et al., 2002; Ribeiro et al., 2012)**. Skin was incised longitudinally for approximately 6 cm from just distal to the medial knee joint, followed by subperiosteal release of superficial medial collateral ligament and pes anserinus from the tibia. Then, a blunt Hohmann retractor was placed along the posterior surface of the proximal tibia to allow protection ofthe neurovascular structures and adequate exposure of the osteotomy site.

Fig.2. Miniaci method of preoperative planning. W1: pre weight bearing line; W2: post weight bearing line; A1/A2: angular lines; O1: predicted osteotomy line; O2: predicted opening line; FP: Fujisawa point;

One or two protective Kirschner wires (K-wires) were inserted from medially to laterally just beneath the articular surface and parallel to the joint line under fluoroscopic guidance. The primary function of these subchondral wires is to prevent propagation of the osteotomy into the articular surface while distraction of the osteotomy gap. The secondary function is to prevent displacement of intra-articular fractures if they are inevitable till appropriate osteosynthesis is achieved.

Another two guide K-wires were sent anteriorly and posteriorly under fluoroscopic guidance to determine the osteotomy line from a point 3–4 cm distal to the medial knee joint and were directed superolaterally to a point 1–1.5 cm distal to the lateral joint line and 1 cm medial to the lateral tibial cortex.

Osteotomy was performed beneath the guide wires using an oscillating saw until the osteotomy line extends to 1 cm medial to the lateral tibial cortexto avoid lateral cortex breakage. After sawing, chisels of increasing widths were hammered step by step into the osteotomy space, followed by gradual and controlled distraction of the osteotomy gap using a laminar spreader. Correction was checked intraoperatively using the cable method (alignment rod or cautery cord)**(Chang et al., 2017)**. After a desired degree of correction was achieved, the plate was fixed. Creation and distraction of the osteotomy was performed under continuous fluoroscopic guidance.

Postoperatively, isometric quadriceps exercise and straight leg-raising exercise were started. Continuous passive motion exercise was allowed. Partial weight bearing was permitted at 3 weeks if radiographs showed signs of consolidation, and full weight bearing was permitted at 6-8 weeks after surgery.

Outcome measurement

Knee function was assessed using the Knee Society Score (KSS) preoperatively, and at 3 and 6 months postoperatively.

Standardized AP and lateral radiographs of the knee as well as weight-bearing AP full-length radiographs were obtained. Radiological evaluation of hip-knee-ankle angle (HKA), medial proximal tibial angle (MPTA), and posterior tibial slope (PTS)(**Fig.3**) was performed preoperatively, and 3 and 6 months postoperatively.

Statistical analysis

Description of means and standard deviation for quantitative variables and frequencies and percentage for qualitative variables were calculated using SPSS Version 22.0 (IBM Corp, Armonk, NY).

Preoperative and postoperative results were compared using paired sample-t-test. Correlation between the change in the PTS and the change in clinical outcomes was examined using Pearson test. The level of significance was set at $P < 0.05$.

Fig.3. PTS measurement using the tibial anatomical axis as reference line.

Results

Demographic data including age, gender, BMI, side, OA grading, associated comorbidities, duration of complaint, and follow-up are summarized in **Table 1**.

Table 1. Demographic Data (N = 20)

	Value
Age (years) *	54.8 ± 7.3
Gender **	
Female	17 (85)
Male	3 (15)
BMI (kg/m^2) *	27.9 ± 3.6
Side **	
Right	11 (55)
Left	9 (45)
Ahlbäck Grading **	
Grade I	8 (40)
Grade II	12 (60)
Comorbidity **	8 (40)
Duration (years) *	2.9 ± 1.1
Follow-up (months) *	8.4 ± 1.6

* Data presented as mean standard deviation
** Data presented as frequency and percentage

Radiological Results

All cases achieved full radiographic union by 3 months. No cases of delayed union or nonunion were reported. The average union time was 2.3 ± 0.5 months, ranging between 1.5 and 3 months.**Table2** demonstrates preoperative, 3-month and 6-month follow-up radiographic parameters, including HKA, MPTA, and PTS.**Fig. 4** illustrate the preoperative and 6-month follow-up radiographs of a 45-year-old female patient with medial compartment OA with varus deformity.

Table 2. Radiographic Results (N = 20)

		***P* value** *
HKA		.000
Preoperative	9.8 ± 2.6	
3 months	-1.4 ± 1.7	
6 months	-1.3 ± 1.7	
MPTA		.000
Preoperative	80.2 ± 2.5	
3 months	91.4 ± 1.6	
6 months	91.3 ± 1.7	
PTS		.000
Preoperative	9.9 ± 2.6	
3 months	11.9 ± 2.9	
6 months	12 ± 2.8	

* Repeated measure ANOVA

Fig. 4. Long-leg, AP, and lateral x-ray views of OWHTO fixed by a Puddu plate (a) preoperative radiographs (b) 6-month follow-up radiographs.

Knee Society Score

As shown in **Figure 5**, the mean preoperative KSS was 96 ± 18 (range, 71 – 127). A significant improvement in KSS was observed at 3 months to a mean of 159 ± 11 (range, 120 – 168) (Post-hoc Bonferroni test, *P* = .000). At 6 months, further improvement in KSS was also found to 172 ± 13 (range, 130 – 189) (Post-hoc Bonferroni test, *P* = .000).

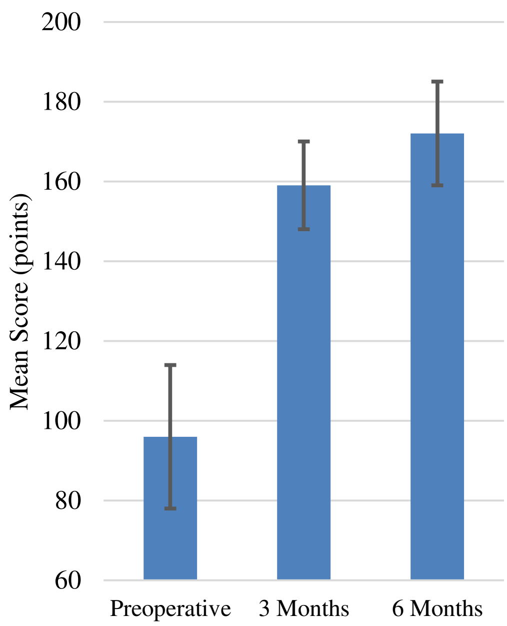

Fig.5. Knee society score

Correlation Analysis

APearson correlation analysis was conducted between changes in PTS and changes in functional parametersat 6-month follow-up. A weak negative correlation was found between variables, where increase in PTS was associated with decreased KSS (r = -0.01). However, the correlation did not reach a statistical significance (*P*> .05).

Complications

Two patients (10%) had superficial infections which were resolved by daily dressing and antibiotic therapy. One (5%) patient had hardware-related symptoms. Two cases (10%) of lateral cortical fracture were reported. No cases showed delayed union or non-union

Discussion

The most important finding of the present study was that OWHTO is associated with an increase in the PTS. However, the short-term results of this procedure showed no correlation between this increase and worsening of knee function.

The literature is replete with varying reports of the effect of OWHTO on PTS. Ozalay et al. **(Ozalay et al., 2008)** found that, following OWHTO, PTS increased in 50 % of patients, decreased in 21 %, and remained unchanged in 29 %. Nevertheless, other studies have demonstrated an increase in PTS associated with OWHTO (**Giffin et al., 2004; Hernigou and Deschamps, 2004; Cullu et al., 2005; Ganji et al., 2013**).

The largest mean increase in PTS was 6.10 degrees [CI: 3.8 to 8.5], reported by Ozel et al, **(Ozel et al., 2017)** whereas the smallest mean increase in PTS was 0.43 degrees [CI: 1.8 to 2.6], reported by Portner et al (**Portner, 2014**). Hinterwimmer et al. **(Hinterwimmer et al., 2011)** did not demonstrate significant changes in PTS following OWHTO. On the other hand, three studies reported a mean decrease in PTS ranging from 0.1 to 0.5 degrees following OWHTO.

In our study, the mean PTS increased from 9.9 ± 2.6 degrees preoperatively to a mean of 11.9 ± 2.9 degrees postoperatively (P = .001). At 6-month follow-up, the mean increase in PTS was 2.1 ± 1.8 degrees with no statistically significant difference was observed between 3- and 6-month measurements (P = .990).

It has been suggested that changes in PTS is a source of instability and excessive anteroposterior tibial translation that may predispose to further progression of osteoarthritis (**Hernigou et al., 1987; Liu and Maitland, 2003; Agneskirchner et al., 2004**). This suggestion was advocated by other biomechanical studies that shown a linear relation between PTS and tibial translation, **(Giffin et al., 2004)** and clinical studies that found a very strong correlation between anterior tibial translation and PTS, in both the healthy knee and the ACL-deficient knee (**Dejour and Bonnin, 1994**).

Despite the fact that PTS has substantial influence of knee stability and tibial translation, limited data exist on the effect of PTS changes on knee functional outcomes (**Dragosloveanu et al., 2014; Ozel et al., 2017**). Dragosloveanu et al. found that, at 2-year follow-up, an average increase in PTS by 1.77° and average increase in knee flexion by 2.56° had no functional impact. Similarly, Ozel et al. showed no significant correlation between the postoperative Lysholm scores and the increase in the PTS angle. In our study, a weak negative correlation was found between PTS and KSS values at 6-month follow-up. However, the correlation was not statistically significant (P> .05).

Previous studies have been concerned with radiographic changes in PTS without taking into account the clinical consequences of such changes in patients' functional outcomes. In the current literature, only two retrospective studies did investigate the clinical impact of PTS changes after OWHTO. To our best knowledge, this is the first prospective study to examine the correlation between changes in PTS and changes in knee functional parameters.

On the other hand, our study had a number of limitations, including the small sample size, the short follow-up period, lack of a control group (e.g., CWHTO), and the use of more than one plate design.

Conclusion

This prospective case series has demonstrated that, at short-term follow-up, OWHTO is associated with a significant increase in PTS. Nevertheless, our findings did not substantiate significant correlation between changes of PTS and clinical outcomes.

Conflict of interest

The authors of the study have no conflict of interest related to this publication.

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