

Effect of the Amount of Correction on Posterior Tibial Slope and Patellar Height in Open-wedge High Tibial Osteotomy

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Abstract

Objectives The effect of amount of correction on postoperative changes in the posterior tibial slope (PTS), patellar height (PH) and clinical outcomes following biplanar open-wedge high tibial osteotomy (OWHTO) were evaluated.

Method This study included 64 knees (30 left, 34 right) of 64 patients (mean age 48.5 ± 6.8 years, 20 males, 44 females) with varus malalignment and symptomatic isolated medial joint osteoarthritis who underwent OWHTO. According to the amount of correction angles, all patients were divided into three groups: large correction angle (LCA) group ($>14^\circ$), medium correction angle (MCA) group (10° – 14°) and small correction angle (SCA) group ($<10^\circ$). All patients were clinically assessed according to the Lysholm score, hospital for special surgery knee score (HSS), and knee society score (KSS) prior to and after surgery. For radiographic analysis, we measured the PTS and PH [Insall-Salvati index (ISI), Blackburne-Peel index (BPI)]. The pre-post difference of PTS, ISI and BPI was calculated by subtracting the post-OWHTO value to the pre-OWHTO value in three groups respectively. The preoperative, postoperative, and difference of PTS, ISI and BPI values were analyzed according to the correction angle. The mean follow-up period was 27.7 months (SD, 3.9; range 12-49 months).

Results Radiologically, PTS increased and PH decreased after surgery on the whole ($p < 0.05$). The relationship between amount of correction and slope increasing is significant ($p < 0.001$). Furthermore, the pairwise difference between the LCA group and SCA group, MCA group are significant respectively ($p < 0.05$). In terms of PH, the LCA group yielded ISI and BPI that were significantly different from baseline for SCA group and MCA group. In addition, the pairwise difference between the SCA group and LCA group in ISI and BPI are significant ($p = 0.031$). Clinically, significant improvements were observed in postoperative clinical scores of the Lysholm score, HSS, and KSS ($p < 0.05$). Fifty-nine patients (92.2%) reported satisfaction with surgery. However, no correlation was found between changes in PTS and PH with postoperative knee score. No severe adverse complications were observed.

Conclusions The amount of correction angle is a significant factor affecting the PTS and PH in OWHTO. With increased correction angle, the likelihood of increasing the PTS and decreasing the PH increases. Special attention should be paid to keep PTS and PH unchanged in cases where large corrections are required. Otherwise, closing wedge osteotomy or other intraoperative effective measures are supposed to be adopted.

Introduction

Biplanar OWHTO (open-wedge high tibial osteotomy) is one of the most effective surgical procedures in the treatment of isolated medial compartment KOA (knee osteoarthritis) with varus¹. Many favourable results for OWHTO have recently been reported²⁻⁴. The main aim of OWHTO is redistribution of load from the medial compartment to the central and lateral areas by correcting the varus deformity of the knee^{5,6}.

Thus, the pressure in medial compartment is decompressed, resulting in pain relieving and delaying of cartilage damage, even partial cartilage regeneration can be observed^{7,8}.

Compared with other types of osteotomy surgery, OWHTO has absolute advantages, such as allowing subtle adjustment in the sagittal and coronal planes, avoiding compromising the peroneal nerve^{9,10}. However, some frequently reported problem associated with OWHTO are unintended increasing PTS (posterior tibial slope) and lowering PH (patellar height)¹¹⁻¹³. Changes of the PH and PTS may result in patellofemoral osteoarthritis and ACL (anterior cruciate ligament) injuries due to increased retropatellar cartilage pressure and higher anteroposterior translation respectively^{14,15}.

Factors influencing PTS and PH in OWHTO are thought as follows: the amount of osteotomy opening, degree of knee flexion, ratio between anterior and posterior gap, status of the lateral hinge and the severity of osteoarthritis present in the knee. Despite numerous studies analyse PH and PTS changes after OWHTO^{1,2,16-18}, only a few studies have briefly claimed effect of the amount of osteotomy opening on PTS and PH in OWHTO through cadaveric model^{19,20}. Also, data on PTS and PH changes and thus resulted clinical outcomes consequent on various osteotomy opening gap are rare.

To the best of our knowledge, there has been no comparative analysis of PH and PTS changes and knee function between different opening gap after OWHTO in clinic. Therefore, this study is aimed to elucidate the influence of different amount of corrections on the changes of PTS, PH and clinical outcomes in vivo after OWHTO for the first time. It was hypothesized that the amount of correction angle is a significant factor affecting the PTS and PH in OWHTO. With increased correction in the coronal plane, the likelihood of increasing the PTS and decreasing the PH increases.

Materials And Methods

Between Nov. 2015 to Dec. 2018, all patients undergoing OWHTO were enrolled in this single-center, retrospective study. The study protocol was approved by the ethics committee of hospital institutional review board. The inclusion criteria were as following: (1) patients with symptomatic varus medial joint OA, (2) range of motion <15° of flexion contracture, (3) varus aligned knee with $\geq 5^\circ$ of mechanical tibiofemoral angle, and (4) medium-to-high level of activity. The Exclusion criteria included (1) lateral and patellofemoral compartments symptoms, (2) previous knee surgery, (3) anterior or posterior cruciate ligament insufficiency with intended slope correction, (4) the presence of rheumatoid arthritis or infectious arthritis, and (5) incomplete or insufficient radiographs.

Surgical procedure

All osteotomies were performed by one senior orthopedist (Y.R.Z.). Preoperative planning (correction angle and amount of opening gap) was determined as previous described by using the Fujisawa point and Miniaci method²¹⁻²³.

An oblique skin incision was made from the insertion of the pes anserinus ascending posterocranially aiming at the posteromedial corner of the tibial head. After soft tissue dissection, the superficial portion of the medial collateral ligament was detached distally. A Hohmann retractor was inserted behind the tibial ridge to protect the neurovascular structure. With the leg fully extended, an exact AP view (one third of the fibular head is covered by tibia) of the knee joint was taken under fluoroscopy. Next, the horizontal osteotomy level was defined by two parallel K-wires, which aim towards the proximal tibiofibular joint, approximately 3.5cm-4cm below the medial joint line. The intraosseous lengths of two wires were measured, and the depth of the saw cut is 10 mm less than the value measured against the wires in order to leave a lateral bone hinge. It's important to ensure that there is sufficient space cranial for the locking bolts of the plate fixator. And, special attention should be paid to osteotomize the complete posterior cortex and to release posterior soft tissue in case of hinge fracture.

Afterwards, with knee flexed to 90°, the anterior ascending osteotomy runs at an angle of 110° to the horizontal saw cut ending behind the patellar tendon insertion. This tuberosity segment should be at least 1.5cm×2cm wide. Using the three-chisel technique, the horizontal osteotomy was gradually opened to desired correction angle²⁴.

The medial tibia was fixed with TomoFix™ Medial High Tibial Plate (Synthes, Solothurn, Switzerland). To minimize tibial slope alteration, the spreader was placed as close to the posterior cortex as possible in addition to the height of the anterior gap of the osteotomy was 60%-70%^{25,26}. The appropriate mechanical axis of the lower extremity was checked with a long alignment rod.

Radiographic and knee function assessments

Preoperative weight-bearing anteroposterior and lateral whole-leg radiographs were obtained to measure PTS, PH and to determine desired correction angle. Also, a skyline view of the knee was taken to evaluate the position changes of patella in coronal plane. The correction angle is defined as angle formed by two lines drawn from the centre of the femoral head and tibiotalar joint to the 62.5% of the tibial width respectively¹⁷. According to correction angle, patients were divided into three groups: LCA (large correction angle) group (≥14°), MCA (medium correction angle) group 10°-14° and SCA (small correction angle) group (<10°). PTS was defined as the narrow angle between the proximal tibial anatomic axis and the line tangent to the joint line (Fig.1). The Insall-Salvati index (the ratio between the length of the deep surface of the patellar tendon and the diagonal length of the patella, ISI) and the Blackburne-Peel index (the ratio between perpendicular distance from the inferior tip of patellar articular surface to proximal tibial articular surface and length of the patellar articular surface, BPI) were used to determine the patellar height^{27,28}. The pre-post difference of PTS, ISI and BPI was calculated by subtracting the post-OWHTO value to the pre-OWHTO value in three groups respectively. Furthermore, the preoperative, postoperative, and difference of PTS, ISI and BPI values were analyzed according to the correction angle.

All patients' knee condition were clinically evaluated preoperatively and at final follow-up using the Lysholm score, HSS (hospital for special surgery knee score), and KSS (knee society score) through

clinical follow-up or telephone follow-up. These measurements were performed by a physician independent of the surgical team and blinded to the radiographic findings. The mean follow-up period was 27.7 months (SD, 3.9; range 12–49 months).

Statistical analysis

All radiographic parameters were collected by two experienced orthopaedic surgeons and repeatedly assessed in a blinded fashion 1 month after the first measurement in order to reduce bias. The interclass correlation coefficients for the intra- and inter-observer agreements were calculated. Statistical evaluation was performed using SPSS 22.0 (IBM Corp., Armonk, NY, USA). The continuous data are presented as mean values \pm standard deviation (SD). Student's *t* test was used to analyze quantitative data, and the chi-squared test was used to analyze qualitative data. The means, SDs, range and differences, comparing the preoperative and postoperative values in the three cohorts, using ANOVA for group comparisons and paired *t*-tests in each group. The *p* values of <0.05 were considered statistically significant.

Results

Between Nov. 2015 and Dec. 2018, 64 patients (20 males, 44 females; 64 knees) who underwent OWHTO were included. The mean patient age was 48.5 years (SD, 6.8; range 19–77 years). The mean body mass index was 26.7 kg/m² (SD 2.5). Among the 64 knees, 34 (53.1%) right knees and 30 (46.9%) left knees were subjected to surgery. To assess the severity of the osteoarthritis in each knee, the K-L (Kellgren-Lawrence) grade were used. There were 17 knees with grade 0, 32 knees with grade 1 and 15 knees with grade 2. The intraobserver reproducibility and interobserver reliability of the (K-L) grade were 0.903 and 0.879, respectively. The demographic characteristics of the included population are listed in Table 1. The interclass correlation coefficients for the intraobserver agreements of the two observer and the interobserver agreement in the values for PTS and PH are showed in Table 2.

Table 1
Demographics Characteristics

| Demographic | SCA group (n = 16 knees) | MCA group (n = 27 knees) | LCA group (n = 21 knees) | Total (n = 64 knees) | P value [▲] |
|---|---------------------------------------|---------------------------------------|---------------------------------------|--------------------------------------|-------------------------|
| Age Mean ± SD (range) | 47.7 years (7.16) (29-55 years) | 48.9 years (6.45) (37-65 years) | 51.5 years (8.56) (19-77 years) | 48.5 years (6.8) (19-77 years) | n.s. |
| Sex | | | | | |
| Female | 9 (56.3) | 16 (59.3) | 12 (57.1) | 37 (57.8) | n.s. |
| Male | 7 (43.7) | 11 (40.7) | 9 (42.9) | 27 (42.2) | |
| Side | | | | | |
| Right | 9 (56.3) | 17 (63) | 13 (61.9) | 39 (60.9) | n.s. |
| Left | 7 (43.7) | 10 (37) | 8 (38.1) | 25 (39.1) | |
| BMI(Kg/m ²) | 25.8 ± 1.6 | 26.1 ± 2.4 | 26.2 ± 1.9 | 26.7 ± 2.5 | n.s. |
| Follow-up period, mo | 28.3 ± 3.1 | 27.8 ± 4.2 | 28.5 ± 3.8 | 27.7 ± 3.9 | n.s. |
| Preop K-L grade | | | | | |
| 0 | 5 (31.2) | 7 (25.9) | 5 (23.8) | 17 (26.6) | n.s. |
| 1 | 7 (43.8) | 14 (51.9) | 11 (52.4) | 32 (50) | |
| 2 | 4 (25) | 6 (22.2) | 5 (28.8) | 15 (23.4) | |
| Mechanical axis correction | 6.91 ± 2.31 | 12.5 ± 1.31 | 14.5 ± 4.5 | 12.8 ± 4.9 | 0.001 |
| LCA: large correction angle; MCA: medium correction angle; SCA: small correction angle; BMI:Body mass index; mo: month; K-L grade: the Kellgren and Lawrence grade; ▲P values are from one-way ANOVA for continuous variables and from chi-square test for categorical variables. | | | | | |

Table 2

Intraclass correlation coefficients for intraobserver and interobserver of PTS, ISI and BPI

| Index | Observer 1 | Observer 2 | Interobserver |
|--|---------------------|---------------------|---------------------|
| PTS | 0.853 (0.667–0.825) | 0.894 (0.815–0.932) | 0.763 (0.577–0.857) |
| PH | | | |
| Insall-Salvati index | 0.867 (0.814–0.928) | 0.931 (0.871–0.961) | 0.838 (0.754–0.915) |
| Blackburne-Peel index | 0.906 (0.923–0.968) | 0.874 (0.847–0.938) | 0.879 (0.835–0.934) |
| PTS: posterior tibial slope; PH: patellar height | | | |

Mean desired correction angle was 12.87°(range 6°–20°); measured postoperative correction angle was 11.92°(range 5.5°–19.7°). Radiologically, the effect of correction angle on changes in PTS and PH were showed in Table 3. The LCA group yielded tibial slopes that were significantly different from SCA group and MCA group. The mean difference of PTS for LCA group was 3.07 ± 2.16 . The difference from baseline PTS is smallest for the SCA group (0.38 ± 1.21) and greatest for the LCA group. In terms of PH, the LCA group yielded ISI and BPI that were significantly different from baseline for SCA group and MCA group. The mean difference of ISI and BPI for LCA group were 0.17 ± 0.21 and 0.17 ± 0.17 respectively. The difference from baseline ISI and BPI all are smallest for the SCA group (0.03 ± 0.24 , 0.01 ± 0.19 , respectively) and greatest for the LCA group.

Table 3
Preoperative and Postoperative Radiological Evaluations

| Variable | SCA group (n = 16 knees) | MCA group (n = 27 knees) | LCA group (n = 21 knees) | P value [▲] |
|--|--------------------------------|--------------------------------|--------------------------------|-------------------------|
| Tibial slope [Mean ± SD (range)] | | | | |
| Preoperative | 7.81 ± 1.52 | 7.91 ± 1.72 | 8.23 ± 1.63 | 0.698 |
| Postoperative | 8.18 ± 2.33 | 9.09 ± 2.49 | 11.3 ± 2.86 | 0.001 |
| Change for postoperative from preoperative | 0.38 ± 1.21 | 1.18 ± 1.6 | 3.07 ± 2.16 | ≍0.001 |
| p value ^{▲▲} | 0.233 | 0.001 | ≍0.001 | |
| Insall-Salvati index [Mean ± SD (range)] | | | | |
| Preoperative | 0.96 ± 0.15 | 0.96 ± 0.1 | 0.97 ± 0.17 | 0.965 |
| Postoperative | 0.93 ± 0.19 | 0.83 ± 0.14 | 0.76 ± 0.11 | 0.004 |
| Change for postoperative from preoperative | -0.03 ± 0.24 | -0.12 ± 0.17 | -0.21 ± 0.2 | 0.03 |
| p value ^{▲▲} | 0.398 | ≍0.001 | ≍0.001 | |
| Blackburne-Peel index [Mean ± SD (range)] | | | | |
| Preoperative | 0.76 ± 0.14 | 0.77 ± 0.13 | 0.77 ± 0.14 | 0.935 |
| Postoperative | 0.75 ± 0.21 | 0.64 ± 0.15 | 0.6 ± 0.12 | 0.025 |
| Change for postoperative from preoperative | -0.01 ± 0.19 | -0.13 ± 0.18 | -0.17 ± 0.17 | 0.031 |
| p value ^{▲▲} | 0.837 | 0.001 | ≍0.001 | |
| ▲P values for comparing the three treatment groups at the same times are from ANOVA; ▲▲P values comparing scores with time in the same treatment group are from paired analysis. | | | | |

The effect of amount of correction on change in PTS was analyzed. The relationship between amount of correction and slope is significant ($p \leq 0.001$). The pairwise difference between the LCA group and the SCA group, MCA group were significant ($p \leq 0.05$). However, the difference in SCA group and MCA group had no significance ($p = 0.435$) (Fig. 2).

The effect of amount of correction on change in PH was also analyzed. The relationship between amount of correction and ISI, BPI were significant respectively ($p = 0.03$, $p = 0.031$). The pairwise difference between the SCA group and LCA group in ISI and BPI are significant ($p = 0.031$); however, the pairwise

difference between the SCA group and MCA group and between MCA group and LCA group had no significance in ISI and BPI respectively ($p=0$) (Fig. 3) (Fig. 4).

Clinically, the preoperative mean Lysholm score, HSS score and KSS score of the knee all had improved substantially after surgery (Table 4). Furthermore, there were significant improvements of knee scores in each three groups respectively, which corresponded to functional results that were excellent in 33 knees, good in 15 knees, fair in 13 knees, and poor in three knees. No correlation was found between changes in PTS and PH with postoperative Lysholm score, HSS score and KSS score. Fifty-nine patients (92.2%) reported satisfaction with surgery.

Table 4
Preoperative and Postoperative Clinical Evaluations

| Variable | SCA group (n = 16 knees) | MCA group (n = 27 knees) | LCA group (n = 21 knees) | Total (n = 64 knees) | P value▲ |
|---|--------------------------------|--------------------------------|--------------------------------|----------------------------|-------------|
| Lysholm score (Mean ± SD) | | | | | |
| Preoperative | 57.6 ± 4.9 | 56.5 ± 5.3 | 56.1 ± 5.5 | 56.7 ± 5.24 | 0.675 |
| Last follow up | 88.1 ± 3.7 | 87.1 ± 5.5 | 86.6 ± 4.9 | 87.17 ± 4.88 | 0.582 |
| p value▲▲ | 0.001 | 0.001 | 0.001 | 0.001 | |
| HSS score (Mean ± SD) | | | | | |
| Preoperative | 61.1 ± 4.7 | 60.2 ± 7 | 59.9 ± 5.6 | 60.33 ± 5.95 | 0.84 |
| Last follow up | 88.9 ± 5.5 | 88.3 ± 6.2 | 87.7 ± 5.4 | 88.28 ± 5.71 | 0.815 |
| p value▲▲ | 0.001 | 0.001 | 0.001 | 0.001 | |
| KSS score (Mean ± SD) | | | | | |
| Preoperative | 58.9 ± 6.5 | 57.8 ± 6.6 | 56.9 ± 5.1 | 57.77 ± 6.1 | 0.614 |
| Last follow up | 83.5 ± 7.8 | 81.2 ± 7.7 | 81.6 ± 6.7 | 81.92 ± 7.36 | 0.609 |
| p value▲▲ | 0.001 | 0.001 | 0.001 | 0.001 | |
| HSS: hospital for special surgery knee score; KSS: knee society score; ▲P values for comparing the three treatment groups at the same times are from ANOVA; ▲▲P values comparing scores with time in the same treatment group are from paired analysis. | | | | | |

With regard to complications, four patients developed non-displaced fractures within the tibiofibular joint intraoperatively (typeⅡ, according to Takeuchi's classification²⁹). Fixation was performed with long metaphyseal cancellous bone screws followed by 4 weeks of delayed postoperative mobilization

exercises. Finally, these patients were observed without obvious functional deficit. Two other patients developed superficial infections, which resolved completely with intravenous antibiotics therapy and wound dressing change.

Discussion

The most important finding of the present study is that correction angle was a significant factor affecting the PTS and PH in patients who underwent OWHTO. The changes are highly variable and often the amount of change is too small to be clinically significant; however, the maximum assessed changes during this study (maximal PTS change 12°, maximal ISI change 0.9 and maximal BPI change 0.75) highlight the need to be vigilant for these problems.

To our knowledge, this is the first clinical study evaluating the effect of different amount of correction on PTS and PH in OWHTO to date. PTS is important for knee extension and flexion, for the correct function of the cruciate ligaments and normal knee kinematics³⁰. In OWHTO, several factors could influence PTS, including the amount of correction²⁰, optimal gap ratio in the sagittal plane^{31–33}, hinge position^{31,32}, hinge fracture, insufficient posterior osteotomy and release of soft tissue^{31,34}. Many studies have demonstrated an increased PTS after OWHTO^{7,17,20,35–37}.

In our study, we observed that the mean postoperative PTS increased. The change of PTS in MCA group and LCA group showed a significant difference compared with preoperative PTS. And, LCA group yielded tibial slopes that were significantly different from SCA group and MCA group, which indicates that the amount of correction performed is one of the key factors affecting the PTS after OWHTO. It is clear that the larger the correction, the more freedom is present for PTS or PH. Matthias et al.²⁰ evaluated the influence of certain intraoperative factors of the degree of PTS change observed during OWHTO through a cadaveric model. They found that larger corrections yielded not only increased mean values for PTS, but also increased variability in the observed values. The changes noted in small corrections were generally below clinical significance; however, in cases with concomitant ACL deficiency, even small changes may be important. This result is consistent with another cadaveric study conducted by Rubino et al.¹⁹. El-Azab et al.³⁸ found that PTS increased after OWHTO because of the geometry of the proximal tibial, which dictates corresponding sagittal plane changes in coronal plane osteotomies. In a recent meta-analysis, an unintentional mean postoperative slope increase of 2.02° has been detected in OWHTO³⁹.

It has been suggested that increased PTS may result in knee instability and tibial translation including increased ACL strain, posteriorly shifted intra-articular cartilage peak pressure. In addition, those patients with increased PTS often underwent more bone loss of the tibial plateau posteriorly, which could make it more difficult to possible future total knee arthroplasty (TKA)⁴⁰. However, the incorporation of specific surgical techniques such as controlling anterior/posterior osteotomy opening gap ratio between 2:3⁴¹; a complete osteotomy of the posterior cortex⁴², putting the plate as far posteriorly as possible⁴³, using reference K-wires for intra-operative PTS orientation⁴⁴, applying a bicortical screw to fix the distal

tuberosity to the tibia⁴⁵ and avoiding larger corrections⁴³ may be helpful in minimizing PTS change. Nevertheless, of course, such an increased PTS can be beneficial in cases of posterior cruciate ligament deficiency, as it can lead to anterior translation of the tibia relative to the femur, especially if ACL deficiency is present⁴⁶.

Ideally, any surgery on the knee should not significantly worsen the position of the patella, making more attention should be paid to avoid patellofemoral issues. A normal PH is an important determinant for knee function, otherwise, may result in anterior knee pain, decreased range of motion, patellofemoral arthrosis, and potentially complicated future TKA^{9,35}. However, we observed that the mean postoperative patellar height decreased after OWHTO in our study. The mean change in ISI and BPI between the SCA group and LCA group are significant ($p < 0.05$), thus we speculated that larger correction angle seems to decrease the patellar position and may have a negative impact on patellar height. In OWHTO, due to the attachment of the tuberosity to the distal fragment, the tibial insertion of the patella is distalized. Also, a potential post-operative tendon shortening caused by scarring may occur.

Hence, in order to avoid a PH decrease, Gaasbeek et al.⁴⁷ introduced a biplanar descending OWHTO, of which sagittal osteotomy line was below the tibial tuberosity. Krause et al.² conducted a study to gain insight into geometric changes of the PH and PTS after biplanar ascending OWHTO compared to descending OWHTO in patients with KOA. They found that descending OWHTO has proven useful to control PH and PTS, which is in line with other previous results^{44,48-50}. However, these techniques are technically demanding and could lead to the potential for fracture of tibial tubercle fragment. Park et al.⁵¹ found two tibial tuberosity fractures with descending OWHTO in 33 patients, but they noted that this complication is preventable by leaving more than 1 cm thickness on the proximal tuberosity fragment.

There was a significant increase in the clinical score after OWHTO. Overall, OWHTO is an effective treatment for isolated medial compartment KOA in varus knees. Patients reported pain relief, improvement in whole-knee function and satisfaction with the clinical outcome. No patellofemoral joint symptoms or other uncomfortable symptoms were observed. Although increased PTS and descent of the patella were observed, postoperative knee scores showed improvement compared with preoperative values, indicating changes of PTS and PH had no meaningful effect on clinical result in short term. In addition, there were no significant differences in terms of postoperative knee scores among three groups, suggesting the effect of different correction angles on knee function and pain was limited.

This study was not without limitations. First, the sample was relatively small and the follow-up was relatively short. Large sample size research and long-term follow-up were required to further evaluate the effect of correction angles on knee joint. Second, the slope was measured only with plain radiographs, and this may predispose to measurement error. But, two experienced observers evaluated radiographic parameters twice in a blinded fashion, which could possibly minimize potential bias from this limitation. Third, no single method of measuring PH has been accepted as the gold standard so far. Each method has its own particular limitations, which is probably why numerous previous studies have used two or three methods.

Conclusion

OWHTO is an effective procedure to unload the medial compartment of knee joint. The amount of correction angle is a significant factor affecting the PTS and PH in OWHTO clinically, although no association was found between those unintended changes and worsening knee clinical symptoms in short term. With increased correction in the coronal plane, the likelihood of increasing the PTS and decreasing the PH increases. We conclude that special attention should be paid to keep PTS and PH unchanged in cases where large corrections are required. Otherwise, closing wedge osteotomy or other intraoperative effective measures are supposed to be adopted.

Abbreviations

OWHTO:open-wedge high tibial osteotomy; KOA:knee osteoarthritis; PTS:posterior tibial slope; PH:patellar height; ACL:anterior cruciate ligament; LCA:large correction angle; MCA:medium correction angle; SCA:small correction angle; HSS:hospital for special surgery knee score; KSS:knee society score; ISI:Insall-Salvati index; BPI:Blackburne-Peel index; K-L:Kellgren-Lawrence

Declarations

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Authors' contributors

YRZ conceived the study. KLW acquired the data. JCZ, KJ, WJF, and XSL developed the analysis plan. XSL and JLC analyzed the data. JCZ and KLW drafted the manuscript. KLW, JCZ, KJ, XSL, WJF, JLC and YRZ revised the manuscript. All authors contributed intellectually to the interpretation of the data, participated in manuscript development, and approved the final version. YRZ is the guarantor.

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Availability of data and materials

No additional data are available.

Ethics approval and consent to participate

Approval was granted by the First Affiliated Hospital of Guangzhou University of Chinese Medicine.

Consent for publication

Not applicable.

Competing interests

The authors declare that they no conflicts of interest.

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Figures

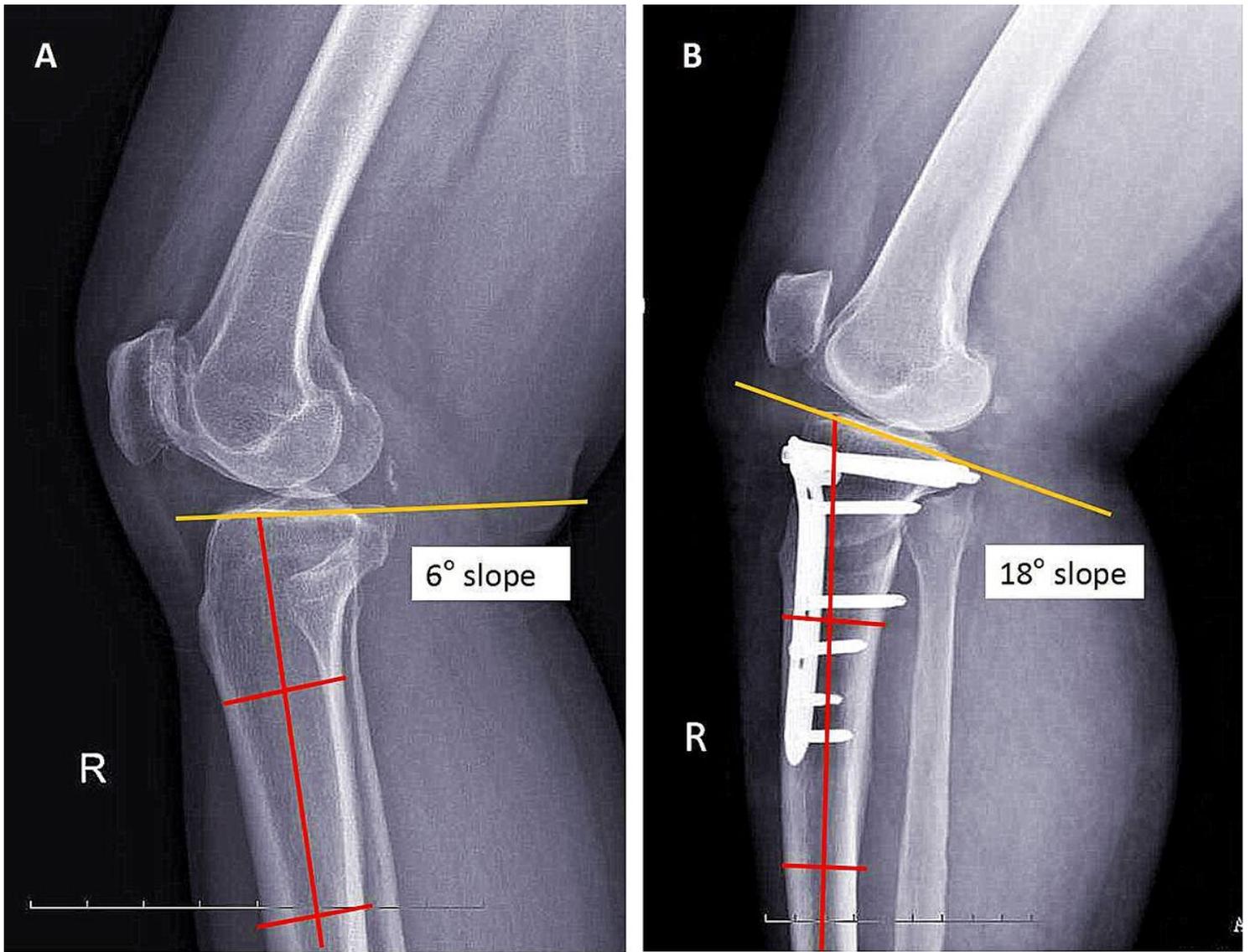


Figure 1

Lateral radiographs obtained A preoperative and B at 36-month follow-up after OWHTO for medial gonarthrosis of the right knee in a 48-year-old female patient with correction angle of 20° . The PTS is the smaller of the two angles shown and is calculated as 90° minus the angle created by the proximal tibial anatomic axis and a line tangent to the joint line (medial tibial plateau).

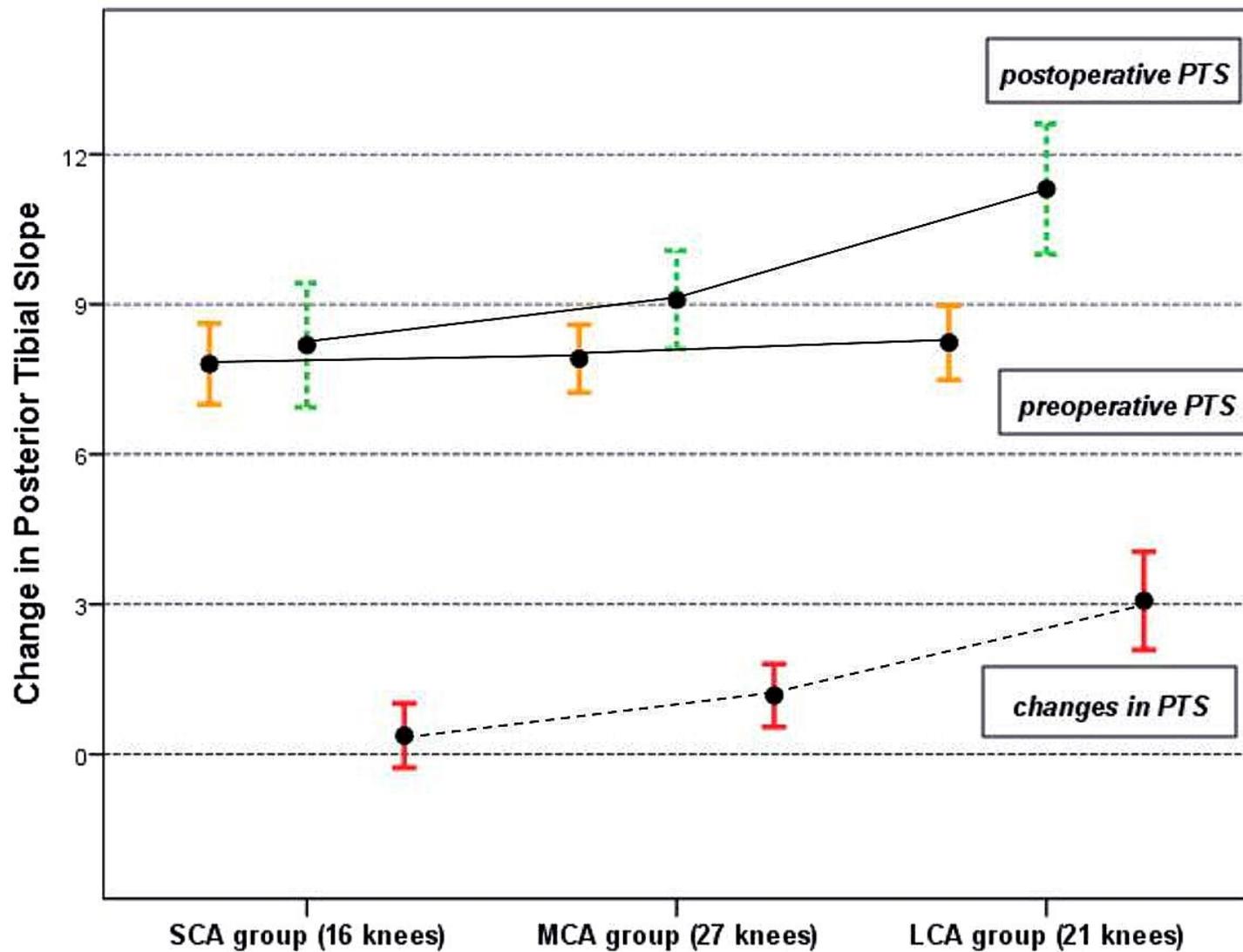


Figure 2

The mean change and 95% CI for the PTS before and after surgery in each of the three groups are shown.

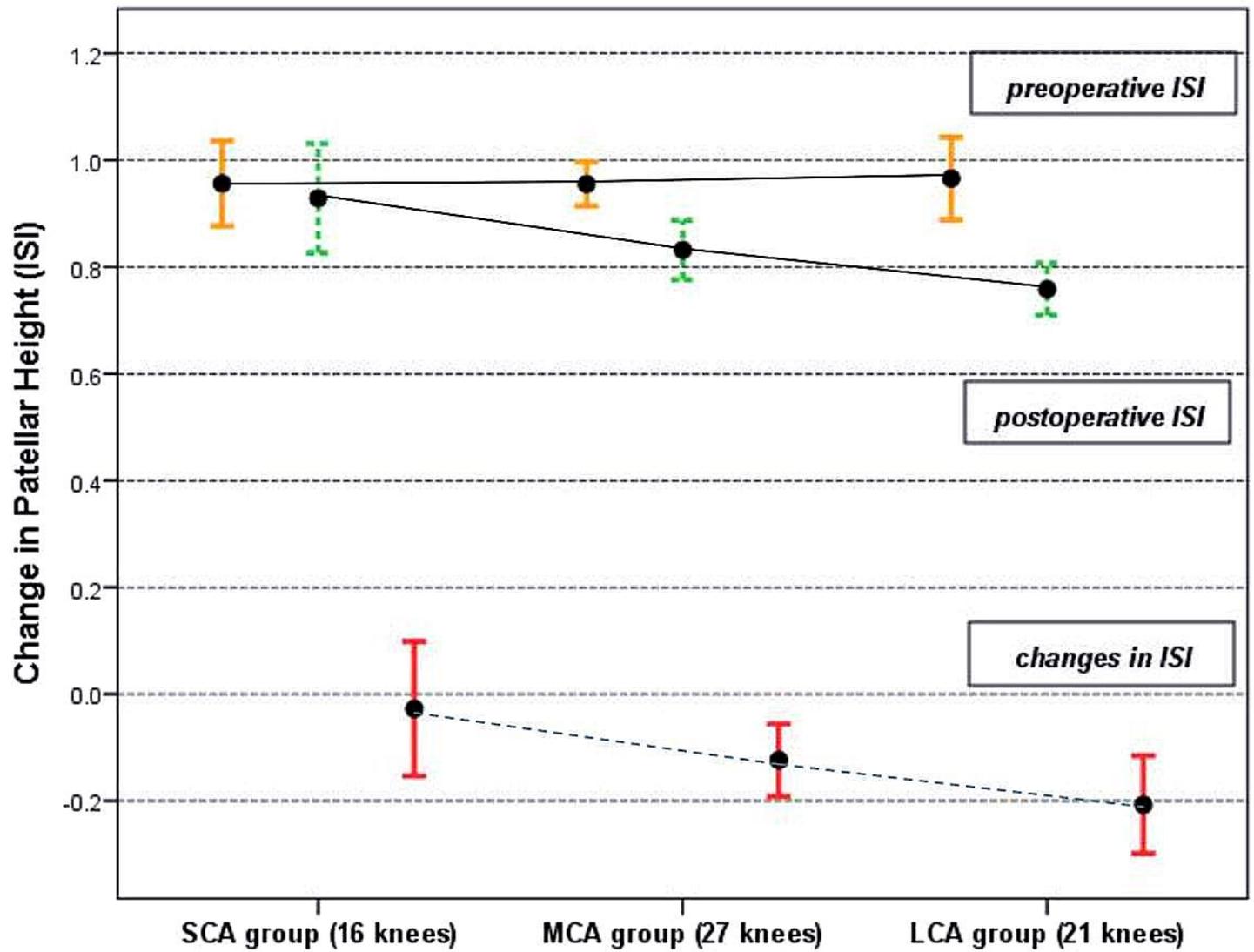


Figure 3

The patellar height of ISI before and after surgery in the three groups with 95% CI are shown.

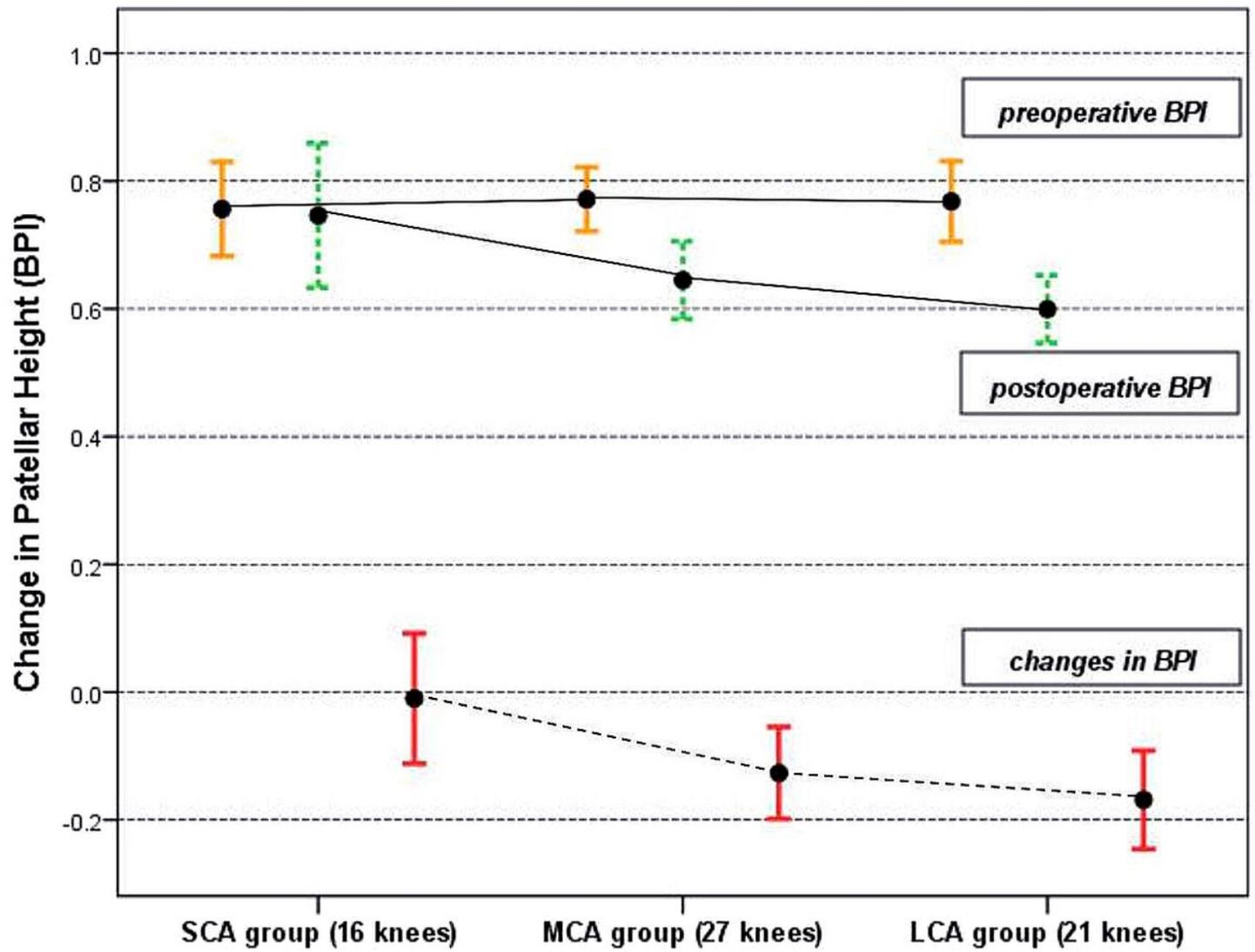


Figure 4

The patellar height of BPI before and after surgery in the three groups with 95% CI are shown.