Original Article

Effect of open-wedge high tibial osteotomy and lateral patellofemoral retinacular release on patellar position: an X-ray imaging-based comparative study

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Background: Open-wedge high tibial osteotomy (OWHTO) may cause adverse changes in the mechanical environment of the patellofemoral joint. For patients with lateral patellar compression syndrome or patellofemoral arthritis, intraoperative management is still challenging. The effect of lateral retinacular release (LRR) on patellofemoral joint mechanics after OWHTO remains unclear. Our study aimed to evaluate the effect of OWHTO and LRR on the patellar position based on lateral and axial radiographs of the knee joint.

Methods: The study comprised 101 knees (OWHTO group) undergoing OWHTO alone and 30 knees (LRR group) undergoing OWHTO and concomitant LRR. The following radiological parameters were statistically analyzed preoperatively and postoperatively: femoral tibial angle (FTA), medial proximal tibial angle (MPTA), weight-bearing line percentage (WBLP), Caton-Deschamps index (CDI), Insall-Salvati index (ISI), lateral patellar tilt angle (LPTA), and lateral patellar shift (LPS). The follow-up duration ranged from 6 to 38 months, with a mean of 13.51±6.84 months in the OWHTO group and 12.47±7.81 months in the LRR group. The Kellgren-Lawrence (KL) grading system was used to evaluate changes in patellofemoral osteoarthritis (OA).

Results: Regarding the patellar height, preliminary analysis demonstrated a statistically significant decrease in the CDI and ISI in both groups ($P<0.05$). However, there was no significant difference in changes in CDI or ISI between the groups ($P>0.05$). In the OWHTO group, although there was a significant increase in the LPTA ($P=0.033$), the postoperative decrease in the LPS was not significant ($P=0.981$). In the LRR group, both the LPTA and LPS significantly decreased postoperatively ($P=0.000$). The mean changes in LPS were 0.03 mm in the OWHTO group and 1.44 mm in the LRR group, indicating a significant change in LPS ($P=0.000$). However, there was no significant difference in changes in LPTA between the groups, which was contrary to our expectations. Imaging showed no change in patellofemoral OA in the LRR group and progressive changes (from KL grade I to II) in patellofemoral OA in 2 (1.98%) patients in the OWHTO group.

Conclusions: OWHTO can cause a significant decrease in patellar height and an increase in lateral tilt. LRR can significantly improve the lateral tilt and shift of the patella. The concomitant arthroscopic LRR should be considered for the treatment of patients with lateral patellar compression syndrome or patellofemoral arthritis.

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Keywords: X-ray; open-wedge tibial high osteotomy; lateral retinacular release (LRR); patellar position

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Introduction

Open-wedge high tibial osteotomy (OWHTO) is a commonly used operation for the treatment of medial compartment osteoarthritis (OA) with varus deformity of the knee joint, and most clinical studies have reported good outcomes (1). However, some biomechanical studies have confirmed that OWHTO will cause adverse changes in the mechanical environment of the patellofemoral joint (2). Clinical reports have also shown that different degrees of patellar height decline, patellar lateral tilt and shift occur after OWHTO (3-5). Changes in patellar position may affect the patellar trajectory and cause patellofemoral OA, which in turn affects patellofemoral joint function (6,7). Therefore, it is mandatory to take some measures to avoid patellofemoral joint problems secondary to OWHTO. It was well described that OWHTO can be performed with distal biplanar osteotomy to not alter patellar height (8). However, for patients with lateral patellar compression syndrome or patellofemoral arthritis before surgery, intraoperative management is still challenging.

Arthroscopic lateral retinacular release (LRR) is mainly used to relieve pressure and solve patellofemoral joint problems (9). Therefore, OWHTO combined with LRR may improve the biomechanics of the patellofemoral joint, thus improving the surgical results and patient satisfaction, but relatively few related clinical reports have been reported. Saito *et al.* (10) and Christodoulou *et al.* (11) reported that LRR can improve the alignment, range of motion and clinical score of the patellofemoral joint. However, they applied closed-wedge osteotomy. Murayama *et al.* (12) found that the patellar height significantly decreased in patients treated with OWHTO alone and OWHTO combined with LRR; however, the lateral patellar tilt and shift were significantly decreased in patients treated with both OWHTO and LRR, while no difference was found in those treated with OWHTO alone. Thus, the effect of LRR on patellofemoral joint mechanics after OWHTO remains unclear.

The objective of this study was to evaluate the effect of LRR on the patellar position in patients undergoing OWHTO based on lateral and axial radiographs of the knee joint. Our hypothesis included three points: (I) lateral, and axial X-rays of the knee joint can be used as a simple and effective method to assess patellar position; (II) OWHTO will cause adverse changes in the patellar position; (III) LRR would improve the patellar position in patients with lateral patellar compression syndrome or patellofemoral arthritis.

Methods

Patients

The subjects of this retrospective study were patients who underwent OWHTO alone (OWHTO group) or OWHTO and concomitant LRR (LRR group) at our hospital from September 2016 to May 2021. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The ethical approval from the Hospital Ethics Committee was obtained for the study design and data acquisition from X-rays (No. 2017009). Because our study did not disclose any private patient data, individual consent for this retrospective analysis was waived.

Our inclusion criteria for receiving OWHTO were (I) isolated medial compartmental OA or osteonecrosis of the medial femoral condyle, which included patients with a varus malalignment of the leg and persistent pain in spite of having undergone conservative treatment for more than 3 months; (II) active compliance with our postoperative rehabilitation program; and (III) a range of motion of more than 120° flexion. The indications for LRR were as follows: (I) preoperative significant anterior knee pain; (II) patellofemoral OA, Kellgren-Lawrence (KL) classification ≥ grade II; (III) patellofemoral cartilage damage visible on arthroscopy, International Association of Cartilage Repair Association (ICRS) grade 3 or 4; and (IV) evidence of lateral patellar compression syndrome on magnetic resonance imaging (MRI) (*Figure 1*). The exclusion criteria were as follows: (I) a follow-up duration of less than half a year; (II) incomplete imaging data; (III) joint infection; (IV) rheumatoid arthritis; (V) complication with lateral compartment OA; (VI) flexion contracture >15°; (VII) descending osteotomy; and (VIII) medial patellar tilt and shift on preoperative imaging or arthroscopy.

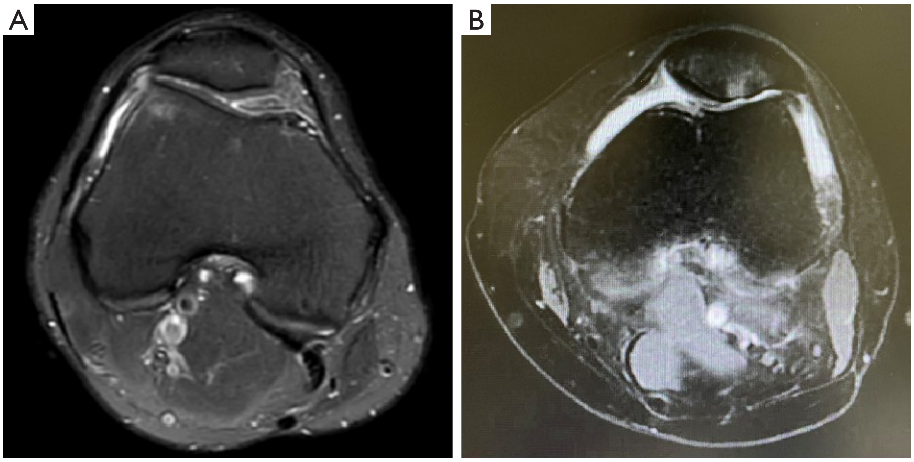

Figure 1 Evidence of patellofemoral cartilage damage and lateral patellar compression syndrome on MRI. (A) The lateral patellar compression syndrome is shown on the horizontal MRI slice of the right knee. (B) The lateral patellofemoral cartilage damage is shown on the horizontal MRI slice of the left knee. MRI, magnetic resonance imaging.

Surgical methods and postoperative rehabilitation

All surgical procedures were performed by the same surgeon (ML) with the patients in a supine position under general anesthesia. All patients underwent a careful, routine arthroscopic inspection and evaluation of the meniscus, ligaments, and articular cartilage and appropriate management if necessary. The anterolateral portal was routinely used to establish the inspection channel (*Figure 2A*), and the anteromedial portal was used to establish the operation channel. First, the hypertrophic inflammatory synovial tissue and synovial folds were removed. In patients with LRR, with the aid of an arthroscopic radiofrequency knife, LRR was completed from the distal to the proximal pole of the lateral border of the patella. The released soft tissue included the superficial and deep layers of the joint capsule and retinaculum (*Figure 2B,2C*). LRR was considered satisfactory when the joint space between the lateral patella and trochlea was enlarged and symmetrically distributed (*Figure 2D*).

An individualized preoperative plan was developed according to the condition of the affected knee to determine the target alignment, wedge width and simulation angle. Commonly used target alignment locations include the tip of the lateral intercondylar spine and the midpoint of the line connecting the medial and lateral intercondylar spines. During the operation, a medial longitudinal incision at the proximal end of the calf was used to expose the medial and posterior aspects of the proximal tibia, and the superficial fibers of the medial collateral ligament were exposed and released. The upper edge of the pes anserinus was the most commonly used marker for the osteotomy. An oblique osteotomy was initiated at a point 35 mm distal to the medial tibial plateau and ending 5 mm from the lateral cortical margin just at the upper level of the proximal tibiofibular joint. A frontal osteotomy was then commenced at a point 10–20 mm proximal to the insertion of the patellar tendon and ending at the first osteotomy plane (biplanar osteotomy). The osteotomy was completed using an oscillating saw and a thin bone knife, maintaining the integrity of the proximal lateral hinge of the tibia. A proximal tibia T-shaped locking plate (Shandong Weigao Medical Instrument Co., Ltd., Weihai, China) was implanted into the subcutaneous tunnel formed by the posteromedial tibia and fixed with 8 locking screws. If the wedge width was more than 10 mm, artificial bone substitute (OSTEOSET, Wright Medical Technology, Inc., USA) was implanted.

Postoperatively, the same rehabilitation protocol was followed in both groups. On the first postoperative day, the patient was allowed to walk with partial weight bearing with the aid of crutches while beginning flexion and extension exercises and straight leg raises. Patients were allowed to walk with full weight bearing without crutches at 2 weeks postsurgery and was discharged within 3 days of their operation.

Radiological measurements

Bilateral standing anteroposterior whole-leg radiographs

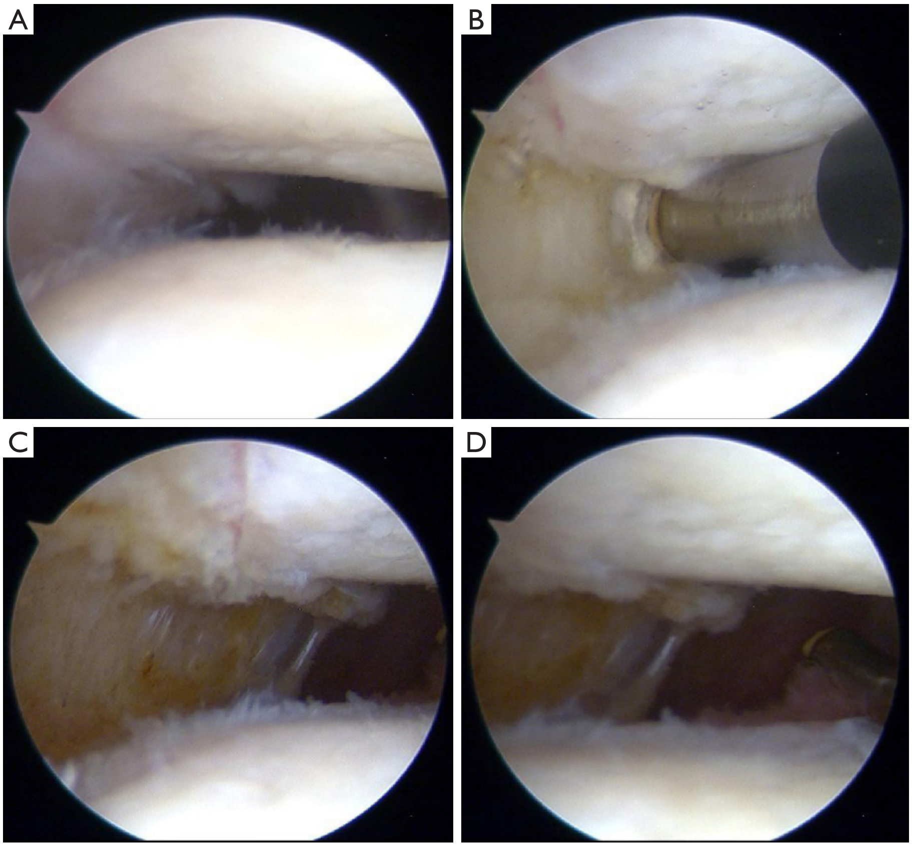

Figure 2 Arthroscopic view of LRR. (A) Lateral joint space before release. (B) Release of the joint capsule. (C) Release of the superficial and deep layers of the lateral retinaculum. (D) Obvious enlargement of the lateral joint space. LRR, lateral retinacular release.

and anteroposterior, lateral, and axial radiographs were obtained from all patients before surgery and at the final follow-up. The whole-leg radiographs were acquired with a 14,351-inch cassette. The axial radiographs were obtained with knee flexion of 30° from the horizontal direction. As previously reported (3-5,12), measurements of the femoral tibial angle (FTA), medial proximal tibial angle (MPTA), and weight-bearing line percentage (WBLP) were obtained from whole-leg radiographs for the assessment of lower extremity alignment. FTA was measured as the angle formed by the intersection of the femoral and tibial mechanical axes. The femoral mechanical axis is the line from the center of the femoral head through the center of the knee, and the tibial mechanical axis is drawn as a line from the center of the ankle to the center of the knee (*Figure 3*). MPTA was the medial angle between two lines: one line of the tibial anatomical axis and a second line extending from the medial to the lateral most area of the tibial plateau, while excluding the osteophyte at the tibial plateau surface. Using a whole leg radiograph, the WBLP was calculated. The denominator was the width of the tibia as measured using a ruler, and the numerator was the tibial intersection of the weight-bearing line (with medial tibial edge at 0% and the lateral tibial edge at 100 %). Measurements of the Caton-Deschamps index (CDI) and Insall-Salvati index (ISI) were performed on a lateral view of the knee at a 30° flexion angle to assess the patellar height. Measurement of CDI and ISI were illustrated in *Figure 4*. Measurements of the lateral patellar tilt angle (LPTA) and lateral patellar shift (LPS) were illustrated in *Figure 5*. All images were imported into the same picture archiving and communications system. Measurements were made on radiographic images using standard digital tools, measuring to 0.1 accuracy (°). The image interpretation and measurements were performed by two senior readers (ML and ZL), who both had more than 10 years of experience in reading study radiographs. If readers disagreed on the measurements, readings were adjudicated by a panel of four readers (two non-author

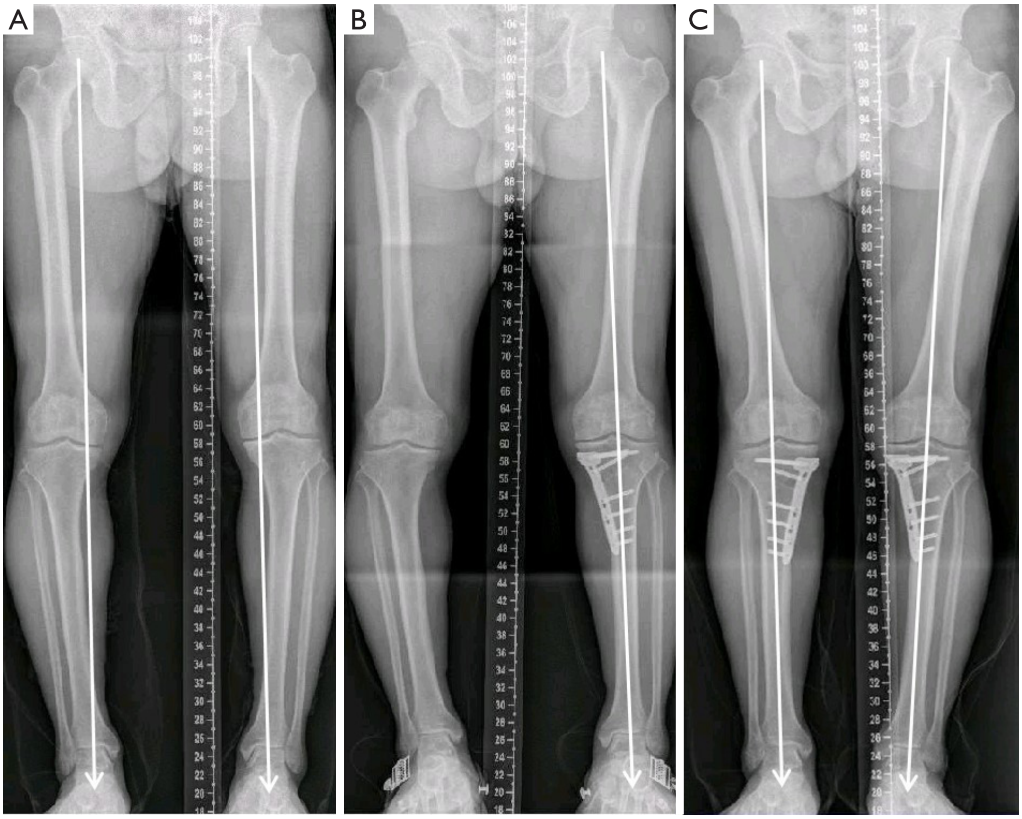

Figure 3 A 61-year-old male patient with bilateral knee varus combined with medial OA. (A) Preoperative full-length radiograph of both lower limbs in standing position showed bilateral knee varus deformity combined with medial space stenosis. (B) Left OWHTO was performed first due to more severe pain in the left knee. (C) Right OWHTO was performed after half a year. OA, osteoarthritis; OWHTO, open-wedge high tibial osteotomy.

radiologists, ML and ZL).

In addition, patellofemoral indices were compared between the two groups. Four patellofemoral parameters were investigated, the first being the height change indicated by the difference in the CDI between before and after surgery, defined as ΔCDI. The second parameter, i.e., ΔISI, also reflected the height change. The third parameter was ΔLPTA, defined as the difference between the pre- and postoperative LPTA. The fourth parameter was ΔLPS, defined as the difference between the pre- and postoperative LPS. In this study, the KL grading system was used to evaluate changes in patellofemoral OA between before and after surgery.

Statistical methods

Data are presented as mean ± standard deviation and range. A paired *t*-test was performed to compare preoperative and postoperative radiographic results. The Mann-Whitney U test was used to statistically analyze differences between the two groups. Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA), and $P<0.05$ was considered to indicate a statistically significant difference.

Results

From September 2016 to May 2021, 209 knees underwent OWHTO at our hospital, and 78 knees were excluded from this study (*Figure 6*). Among them, incomplete imaging data were available for 53 knees, the follow-up duration was less than half a year for 21 knees, and descending osteotomy was performed on 4 knees. In total, 131 knees met the study criteria (101 knees in the OWHTO group, 30 knees in the LRR group). Preoperative demographic and clinical characteristics in both groups are comparatively

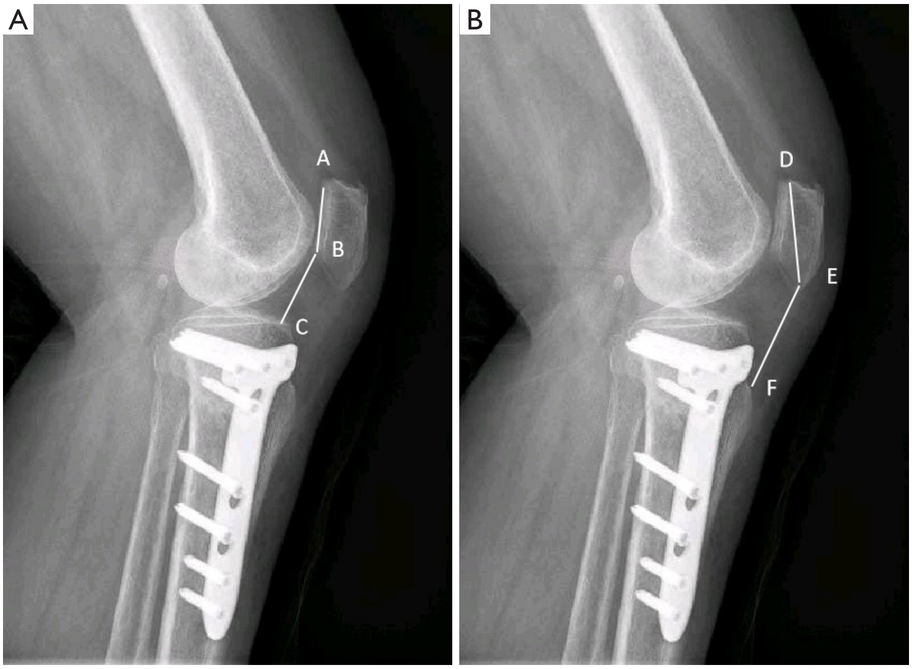

Figure 4 Schematic diagram of CDI and ISI measurement on knee X-ray. (A) In the lateral radiograph of the knee, the CDI is the ratio of the distance BC from the lower end of the patellar articular surface to the anterior superior angle of the tibia to the length of the patellar articular surface AB. (B) In the lateral radiograph of the knee, the ISI is the ratio of the length of patellar tendon EF to the longest length of patella DE. CDI, Caton-Deschamps index; ISI, Insall-Salvati index.

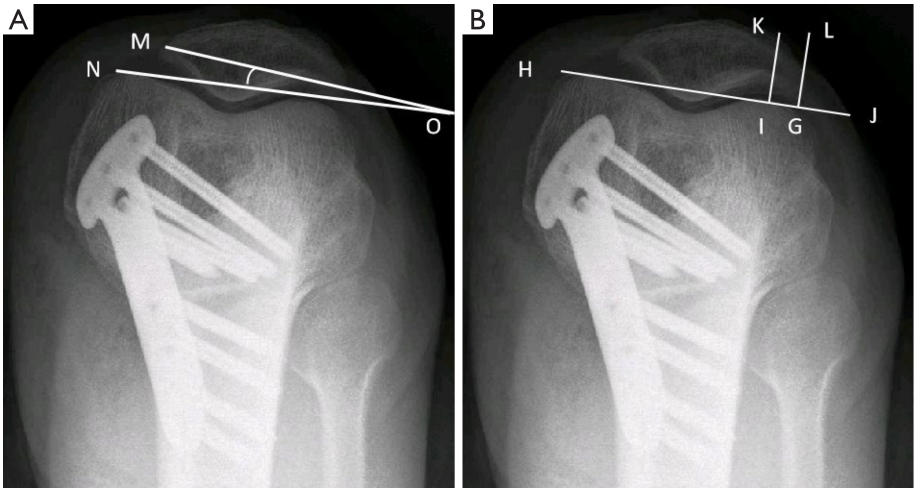

Figure 5 Schematic diagram of LPTA and LPS measurement on knee X-ray. (A) In the axial radiograph, LPTA is defined as the angle between the line intersecting the widest bony structure of the patella MO and the line passing the anterior surfaces of the femoral condyles tangentially NO. (B) In the axial radiograph, LPS is defined as the distance between the summit of the lateral femoral condyle IK and a line from the lateral edge of the patella GL that is perpendicular to the line that passes through the summits of the femoral condyles HJ. LPTA, lateral patellar tilt angle; LPS, lateral patellar shift.

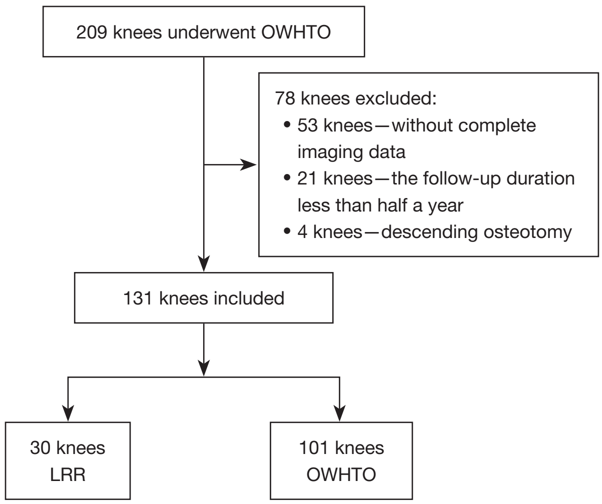

Figure 6 Patient selection diagram. OWHTO, open-wedge high tibial osteotomy; LRR, lateral retinacular release.

Table 1 Basal characteristics of patients in the two groups

Characteristics	OWHTO group	LRR group	P value
No. of knees	101	30	
Age (years)	56.07±7.44	57.87±8.01	0.484
Female	65 (64.36)	21 (70.00)	–
Treatment of right knee	61 (60.40)	17 (56.67)	–
BMI (kg/m^2)	23.95±2.23	24.42±2.51	0.711
Duration (months)	8.81±5.72	8.67±6.23	0.987
Simulation angle (°)	9.48±1.87	9.63±2.81	0.055
Operation time (min)	53.62±4.32	62.03±4.48	0.388
Follow-up duration (months)	13.51±6.84	12.47±7.81	0.350

Data are presented as mean ± standard deviation or n (%). OWHTO, open-wedge high tibial osteotomy; LRR, lateral retinacular release; BMI, body mass index.

shown in *Table 1*. In the OWHTO group, 64.36% (65 of 101) of patients were women, and 60.04% (61 of 101) of patients underwent treatment of the right knee. In the LRR group, 70% (21 of 30) of patients were women, and 56.67% (17 of 30) of patients underwent treatment of the right knee. No differences in age, body mass index (BMI), condition duration, simulation angle or follow-up duration were observed between the two groups (P>0.05). The mean operation time was 53.62 min in the OWHTO group and 62.03 min in the LRR group, but there was no statistically significant difference (P=0.388).

Pre- and postoperative values measured for each of the radiological parameters in both groups are comparatively shown in *Table 2*. Regarding the patellar height, preliminary analysis demonstrated a statistically significant decrease in the CDI and ISI from baseline to the last follow-up in both groups (P<0.05). In the OWHTO group, 73.26% (74 of 101) of patients showed a decrease in the CDI and an average decrease of 6.72% in patellar height, while 73.33% (22 of 30) of patients in the LRR group showed a decrease in the CDI and an average decrease of 7.3% in patellar height. In the OWHTO group, 76.24% (77 of 101) of the patients showed a decrease in the ISI and an average decrease of 11.51% in patellar height, while 76.67% (23 of 30) of the patients in the LRR group showed an average decrease of 12.65% in patellar height. However, there were different results regarding the LPTA and LPS in the two groups. In the LRR group, both the LPTA and LPS significantly decreased after surgery (P=0.000). In the OWHTO group, although a significant increase in the LPTA was observed (P=0.033), the postoperative decrease in the LPS did not reach the level of statistical significance (P=0.981).

Changes in patellar parameters in the two groups are shown in *Table 3*. The mean ΔLPS was 0.03 in the OWHTO group and 1.44 in the LRR group, indicating a significant change in the LPS (P=0.000). There was no significant difference, however, in ΔLPTA between the two groups, which was contrary to our expectations. Assessment of the patellar height showed no significant difference in the ΔCDI or ΔISI between the two groups (P>0.05).

Imaging showed progressive changes in patellofemoral arthritis in 2 knees (1.98%) in the OWHTO group, with increases to KL grades I and II in 1 case each (*Figure 7*). In contrast, in the LRR group, imaging showed not only no progressive changes in any knee with patellofemoral OA but also a decrease from KL grade III to KL grade II in 2 knees (*Figure 8*).

Discussion

Regarding the patellar height, preliminary analysis of the study demonstrated a statistically significant decrease in the CDI and ISI in both groups. However, there was no significant difference in ΔCDI or ΔISI between the groups. In the OWHTO group, although there was a significant increase in the LPTA, the postoperative decrease in the LPS was not significant. In the LRR group, both the LPTA and LPS significantly decreased postoperatively. The mean

Table 2 Pre- and postoperative radiological values in the two groups

Measurement	OWHTO group			LRR group		
	Preoperative	Postoperative	P value	Preoperative	Postoperative	P value
FTA (°)	7.52±2.42 (varus)	2.34±2.35 (valgus)	0.000	7.45±2.72 (varus)	2.72±2.35 (valgus)	0.000
MPTA (°)	81.73±1.8	90.84±2.32	0.000	81.25±1.99	90.91±2.71	0.000
WBLP (%)	17.15±12.03	56.33±9.12	0.000	16.04±12.97	58.66±10.19	0.000
CDI	0.97±0.16	0.90±0.10	0.000	0.97±0.14	0.90±0.19	0.012
ISI	1.09±0.13	0.97±0.19	0.000	1.08±0.15	0.95±0.13	0.000
LPTA (°)	8.28±4.12	9.23±4.02	0.033	10.16±3.88	6.57±3.20	0.000
LPS (mm)	2.84±2.68	2.77±2.72	0.981	3.33±2.91	1.88±2.29	0.000

Data are presented as mean ± standard deviation. OWHTO, open-wedge high tibial osteotomy; LRR, lateral retinacular release; FTA, femoral tibial angle; MPTA, medial proximal tibial angle; WBLP, weight-bearing line percentage; CDI, Caton-Deschamps index; ISI, Insall-Salvati index; LPTA, lateral patellar tilt angle; LPS, lateral patellar shift.

Table 3 Changes in patellar parameters in the two groups

Values	OWHTO group	LRR group	P value
ΔCDI	0.07±0.12	0.07±0.13	0.672
ΔISI	0.12±0.2	0.13±0.14	0.134
ΔLPTA (°)	–0.96±3.05	3.46±3.84	0.271
ΔLPS (mm)	0.03±2.04	1.44±1.85	0.000

Data are presented as mean ± standard deviation. Δ represents the preoperative value minus the postoperative value. OWHTO, open-wedge high tibial osteotomy; LRR, lateral retinacular release; CDI, Caton-Deschamps index; ISI, Insall-Salvati index; LPTA, lateral patellar tilt angle; LPS, lateral patellar shift.

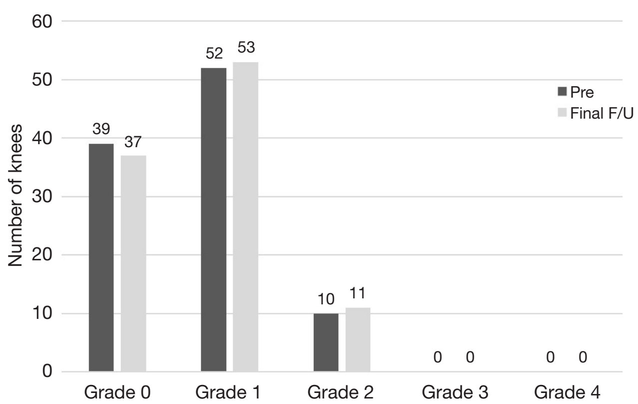

Figure 7 OA changes in the patellofemoral joint assessed with the KL grading system in the OWHTO group. Pre, preoperative; F/U, follow-up; OA, osteoarthritis; KL, Kellgren-Lawrence; OWHTO, open-wedge high tibial osteotomy.

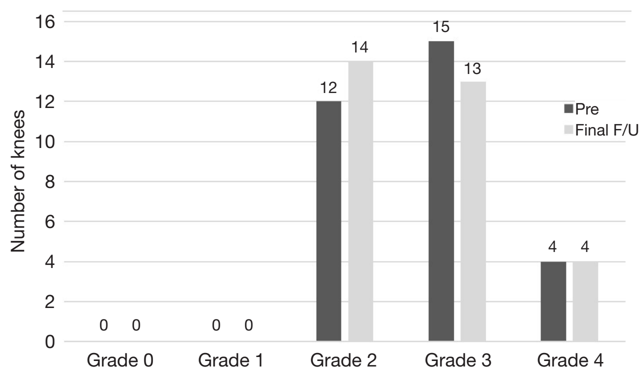

Figure 8 OA changes in the patellofemoral joint assessed with the KL grading system in the LRR group. Pre, preoperative; F/U, follow-up; OA, osteoarthritis; KL, Kellgren-Lawrence; LRR, lateral retinacular release.

ΔLPS was 0.03 mm in the OWHTO group and 1.44 mm in the LRR group, indicating a significant change in LPS. However, there was no significant difference in ΔLPTA between the groups, which was contrary to our expectations. Imaging showed no change in patellofemoral OA in the LRR group and progressive changes (from KL grade I to II) in patellofemoral OA in 2 (1.98%) patients in the OWHTO group.

It was believed that OWHTO would cause distal displacement of the tibial tubercle and increase the tension of the patellar tendon, resulting in a decrease in patellar height. In addition, the osteotomy position was close to the patellar tendon, which may lead to the formation of patellar tendon scar contracture after the operation, which may explain the decrease of CDI and ISI. A study reported that 80% of patients showed a patellar height reduction after OWHTO (13). Amzallag *et al.* (14) found that the patellar height decreased by an average of 9% after OWHTO. Otsuki *et al.* (5) found that the OWHTO correction angle was negatively correlated with the CDI; when the correction angle was 1°, the CDI decreased by 1.7%. A study by Otakara *et al.* (13) suggested that degeneration of the patellofemoral joint should be considered when correcting MPTA >10° and recommended adjustment of the surgical plan before surgery. Bito *et al.* (15) believed that a correction angle in OWHTO exceeding 15° would adversely affect the patellofemoral joint. Tanaka *et al.* (7) found progressive changes in patellofemoral articular cartilage injury after OWHTO with a distraction gap greater than or equal to 13 mm or a corrected MPTA greater than or equal to 9°. Lee *et al.* (4) found that a mechanical shaft valgus angle >5.1° after OWHTO could cause degenerative progression of the patellofemoral joint.

Horikawa *et al.* (8) reported that distal biplanar osteotomy maintained the preoperative patellar height, which could help prevent progression of cartilage degeneration in the patellofemoral joint after surgery.

However, there is still no consensus on the effect of OWHTO on patellar tilt and shift. Bito *et al.* (15) found a significant decrease in the LPTA and no significant difference in the LPS after OWHTO and argued that this may have been caused by the relative distal displacement and small lateral displacement of the tibial tubercle. In a biomechanical study, Gaasbeek *et al.* (16) analyzed the reasons for the decreased patellar tilt angle. They believed that after OWHTO, the lateral surface of the patella was pressed against the lateral wall of the trochlea, causing medial tilt. In addition, a recent MRI study also reported a decrease in the LPTA after OWHTO (17). Lee *et al.* (4) found that after OWHTO, the LPTA and LPS did not change. However, we found that the inclusion criteria of the abovementioned studies were relatively broad, and patients with patellofemoral arthritis or lateral patellar compression syndrome were not considered separately, which may have affected the results and conclusions of the study. In our study, the LPTA of patients in the OWHTO group significantly increased from 8.28°±4.12° before surgery to 9.23°±4.02° after surgery (P=0.033), indicating that OWHTO may have an adverse effect on patellar lateral tilt.

LRR is a commonly used minimally invasive arthroscopic technique that is characterized by a simple operation and is mainly used to reduce pressure on the patellofemoral joint and solve patellofemoral joint problems (9). Studies have shown that in patients with lateral patellar hypertension, pain is significantly improved in the short term after LRR (18). In a systematic review of the literature on arthroscopic LRR for anterior knee pain, Lattermann *et al.* (19) observed good outcomes in 76% of patients and a low complication rate. There have also been reports on the application of LRR in the treatment of patellofemoral OA. Alemdaroğlu *et al.* (20) conducted a prospective study of 35 patients over 50 years of age with grade II to IV patellar cartilage injuries who underwent LRR and radiofrequency cartilage debridement. The authors observed significant improvements in pain and function within 2 years. Biomechanical studies have also shown that LRR can relieve pressure on the lateral surface of the patella (21). These findings provide a theoretical basis for the application of LRR in the treatment of anterior knee pain and patellofemoral OA.

Therefore, concomitant LRR during HTO may improve the biomechanics of the patellofemoral joint, thereby improving surgical outcomes and patient satisfaction, but related studies are still relatively rare. Saito *et al.* (10) reported that LRR combined with closed-wedge HTO can improve patellofemoral joint involution. Christodoulou *et al.* (11) also reported that HTO combined with LRR could provide better patellofemoral joint alignment, range of motion and clinical scores than HTO alone. However, their HTO procedure was a closed-wedge osteotomy. Murayama *et al.* (12) divided patients into an OWHTO group and an OWHTO combined with LRR group. They found that the patellar height decreased significantly after surgery in both groups and that the LPS and ectropion were significantly reduced in the LRR group, but without a significant difference between the groups. However, the study did not include patients with anterior knee pain or patellofemoral arthritis, and the two groups of patients were not operated on by a single surgeon, which may have affected the results. Based on previous reports, this study included patients with preoperative anterior knee pain or patellofemoral arthritis and found that the patellar inclination and lateral displacement were significantly reduced in the LRR group. In addition, the mean ΔLPS was 0.03 in the OWHTO group and 1.44 in the LRR group, indicating a significant decrease in LPS (P=0.000). These findings suggest that concomitant LRR may result in a reduction in patellofemoral joint pressure.

The effect of changes in patellar position after OWHTO on patellofemoral OA was also a concern. Goshima *et al.* (22)

found that patellofemoral OA developed in 15 knees (27%), and arthroscopy showed patellofemoral cartilage degeneration in 27 knees (45%), mainly manifesting in the joint formed by the lateral surface of the patella and the lateral wall of the trochlea. These findings may be direct evidence of lateral patellar tilt. In our OWHTO group, imaging showed progressive changes in patellofemoral arthritis in 2 knees (1.98%), with increases to KL grades I and II in one case each. In contrast, in the LRR group, imaging showed not only no progressive changes in any knee with patellofemoral OA but also a decrease from KL grade III to II in two knees. We believe that OWHTO combined with LRR may improve patellofemoral alignment.

There are a number of limitations to the present study. First, this is a retrospective design study. A more strictly designed prospective randomized controlled study is needed to explore the effect of LRR on patella position and patellofemoral joint function. Second, the patellofemoral alignment was only evaluated using lateral and axial view, without considering the effect of torsion on patellofemoral arthritis. It was reported the measurement of proximal tibial deformity showed high variability in the two-dimensional and three-dimensional analysis in the designed mathematical models (23). Third, this study only evaluated the radiological parameters in both groups, not a specific assessment for the clinical outcome of patellofemoral joint. Finally, lack of direct evidence of cartilage repair, long-term cartilage status and degenerative change is still questionable. Therefore, in the future, patients should be evaluated for cartilage damage, particularly the patellofemoral joint, over time.

Conclusions

Based on lateral and axial radiographs of the knee joint, we found that the patellar height significantly decreased after OWHTO in both groups as assessed by the CDI and ISI. The LPTA and LPS were significantly improved in the LRR group. However, after OWHTO alone, the LPTA increased significantly, with no significant change in LPS. The concomitant arthroscopic LRR should be considered for the treatment of patients with lateral patellar compression syndrome or patellofemoral arthritis.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-926/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The ethical approval from the Hospital Ethics Committee was obtained for the study design and data acquisition from X-rays (No. 2017009). Because our study did not disclose any private patient data, individual consent for this retrospective analysis was waived.

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