

# Are There Harmful Effects of Preoperative Mild Lateral or Patellofemoral Degeneration on the Outcomes of Open Wedge High Tibial Osteotomy for Medial Compartmental Osteoarthritis?

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**Background:** Early osteoarthritis of the knee joint mostly affects the medial compartment, making osteotomy a rational approach to slow the progression of the disease. However, some patients show asymptomatic mild degeneration in the lateral or patellofemoral compartment.

**Purpose:** To evaluate the effect of asymptomatic mild lateral or patellofemoral degeneration on the outcomes of medial open wedge high tibial osteotomy (OWHTO) by assessing the outcomes according to the preoperative status of the lateral or patellofemoral degenerative changes.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** A total of 114 patients (121 knees) who underwent biplanar OWHTO with second-look arthroscopic surgery and postoperative magnetic resonance imaging (MRI) were retrospectively enrolled. Patients were categorized into 4 groups according to the Osteoarthritis Research Society International (OARSI) and MRI Osteoarthritis Knee Score (MOAKS) classification systems. The International Cartilage Repair Society (ICRS) grade was used to evaluate the preoperative and postoperative cartilage status. Clinical outcomes were assessed by the American Knee Society (AKS) score, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and 36-item Short Form Health Survey (SF-36).

**Results:** No degenerative changes in the lateral and patellofemoral compartments of knees (group I) were identified in 51.2% of cases (62 knees). Asymptomatic degenerative changes only in the lateral compartment (group II: OARSI grades 1-3 and MOAKS grades 1-3) were identified in 15.7% of cases (19 knees), changes only in the patellofemoral compartment (group III: OARSI grades 1-3 and MOAKS grades 1-3) were identified in 10.7% of cases (13 knees), and changes in both the lateral and the patellofemoral compartments (group IV) were identified in 22.3% of cases (27 knees). In the medial compartment, there was no significant difference in the improvement of MOAKS and ICRS grades among all groups ( $P = .813$  and  $.985$ , respectively). In the lateral and patellofemoral compartments, there was no significant difference in the decline of MOAKS ( $P = .649$  and  $.421$ , respectively) and ICRS grades ( $P = .927$  and  $.676$ , respectively) among all groups.

**Conclusion:** The presence of mild lateral or patellofemoral degenerative changes did not affect the MRI, arthroscopic, and clinical outcomes of OWHTO. However, long-term observations are necessary to draw definitive conclusions as to whether OWHTO can be indicated in such patients without harmful effects.

**Keywords:** lateral compartment; patellofemoral compartment; osteophytes; osteoarthritis; open wedge high tibial osteotomy

Medial open wedge high tibial osteotomy (OWHTO) is an effective surgical procedure for the treatment of medial compartmental osteoarthritis (OA) with coexisting varus deformities of the knee.<sup>6,8</sup> Therefore, this procedure has

traditionally been indicated only in cases of medial compartment involvement and is generally contraindicated in cases of OA involving other compartments, such as the lateral or patellofemoral compartments.<sup>4,10,12</sup>

Early OA of the knee joint mostly affects the medial compartment, making osteotomy a rational approach to slow the disease progression and reduce pain by altering the load distribution through the knee.<sup>14,20</sup> However, the

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pathogenesis of OA is complicated and multifactorial. It includes metabolic imbalances or microscopic changes and can involve any part of the cartilage, bone, and synovium.<sup>25</sup> Therefore, it can be assumed that all 3 compartments may be involved to some extent, even though degeneration or symptoms are mostly limited to the medial compartment. This phenomenon can sometimes be seen in preoperative evaluations; further, some patients show osteophyte formation or mild degeneration in the lateral or patellofemoral compartment on plain radiography or magnetic resonance imaging (MRI) even when there are no symptoms in these compartments. In this circumstance, it may be unreasonable to convert the procedure to joint replacement surgery just to treat mild asymptomatic degenerative changes. It is also unknown whether the outcomes of OWHTO in these types of affected patients will be affected.

Most researchers agree that OWHTO adversely affects the lateral or patellofemoral joint to some extent because of load redistribution in these compartments.<sup>12,13,23</sup> However, there is limited consensus on what degree of degeneration in other compartments is permissible or contraindicated for OWHTO. Unicompartmental knee arthroplasty (UKA) is often compared with high tibial osteotomy (HTO) because they share some indications, although they are different procedures. One major difference is that OWHTO converts the knee to a valgus alignment while medial UKA typically maintains some varus alignment. Some studies have reported that mild lateral or patellofemoral compartmental OA has minimal effects on the outcomes of medial UKA; it is unknown if this finding can be similarly assumed in OWHTO.<sup>3,7</sup>

The purpose of this study was to evaluate the effect of asymptomatic mild lateral or patellofemoral degeneration on the outcomes of medial OWHTO by assessing the outcomes according to the preoperative status of the lateral or patellofemoral degenerative changes. The hypothesis was that mild asymptomatic degenerative changes in the lateral or patellofemoral compartment would not affect the outcomes of OWHTO.

## METHODS

From March 2014 to April 2016, a total of 178 consecutive knees that underwent biplanar OWHTO and plate removal after union with second-look arthroscopic surgery were enrolled in this retrospective study. OWHTO was performed in all patients with a diagnosis of medial compartmental OA. The inclusion criteria for this study were as

follows: (1) primary degenerative OA (not inflammatory arthritis), (2) radiographic evidence of prominent medial compartmental OA (Kellgren-Lawrence [KL] grades 2-4), (3) asymptomatic patients (patients without lateral joint-line tenderness and anterior knee pain) with radiographic evidence of medial compartmental OA with minimal degenerative changes in the lateral (osteophyte formation and signal change up to KL grade 1) or patellofemoral (osteophyte formation and signal change up to KL grade 1) compartment, (4) concurrent varus deformities of the lower limb (5°-15° of varus), and (5) failure of nonoperative treatment. There were 10 knees excluded for having a history of the following surgical procedures: (1) double osteotomy (4 knees), (2) combined anterior cruciate ligament reconstruction (4 knees), (3) revision HTO (1 knee), and (4) multiple fracture surgery around the knee joint (1 knee). The knees without postoperative MRI scans and second-look arthroscopic images were also excluded (47 knees).

Consequently, 121 knees in 114 patients were included (Figure 1). Plain radiographic results, MRI findings, arthroscopic findings, and clinical outcomes were used for the assessment. All assessments were reviewed by 2 blinded independent observers (D.H.K., S.C.K.) at a 2-week interval. Institutional review board approval was obtained before performing any analysis.

## Plain Radiographic Evaluation

INFINITT version 5.0.9.2 (INFINITT Healthcare) was used for all radiographic measurements and grading. Standing anteroposterior, 45° posteroanterior, lateral, Merchant, and hip-knee-ankle (HKA) weightbearing radiographs were obtained preoperatively, immediately after index surgery, and at the final follow-up for a routine evaluation. The preoperative HKA angle and weightbearing line (WBL) ratio were evaluated. The WBL ratio was calculated as the percentage of the crossing point of the mechanical axis from the medial edge of the tibial plateau to the entire width of the tibial plateau.

Preoperative osteophytes and joint space narrowing of the lateral and patellofemoral compartments were assessed using the Osteoarthritis Research Society International (OARSI) classification system. The OARSI classification system is an atlas-based grading system with grades ranging from 0 (no osteophytes) to 3 (large osteophytes) for osteophyte formation and from 1 (normal) to 3 (lateral tibiofemoral narrowing) for narrowing of the lateral compartment (Figure 2).<sup>2</sup> The lateral or patellofemoral compartment was scored on the basis of the largest osteophytes and the narrowest area observed. Moreover,

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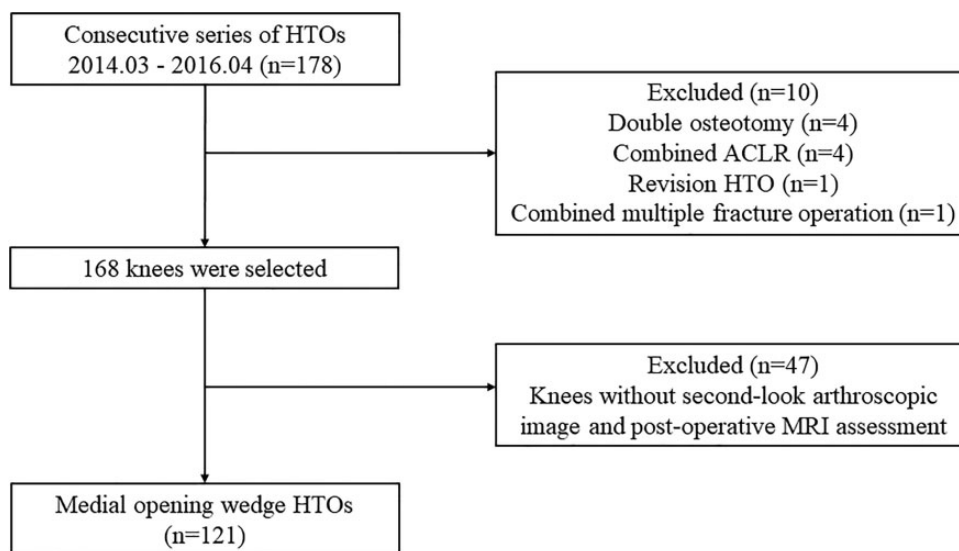
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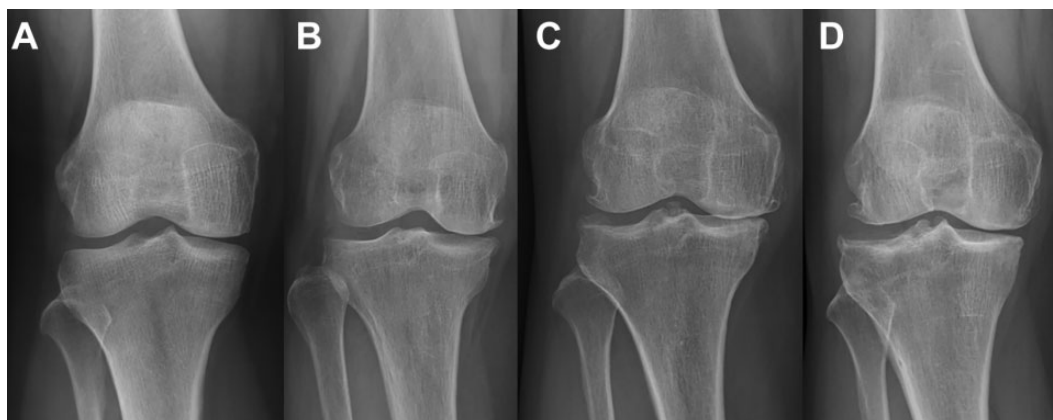
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Ethical approval for this study was obtained from the Seoul National University Bundang Hospital Institutional Review Board (study No. B-1911/577-103).



**Figure 1.** Flowchart of patient enrollment. ACLR, anterior cruciate ligament reconstruction; HTO, high tibial osteotomy; MRI, magnetic resonance imaging.



**Figure 2.** Osteoarthritis Research Society International (OARSI) grade of osteophytes in the lateral compartment: (A) grade 0 (none), (B) grade 1 (small size osteophytes in lateral femur and tibia), (C) grade 2 (medium size osteophytes in lateral femur and tibia), and (D) grade 3 (large size osteophytes in lateral femur and tibia).

patellofemoral joint space narrowing on Merchant radiographs was classified into 4 grades according to the system by Merchant et al<sup>19</sup>; this classification ranges from grade 1 (mild with >3 mm of joint space) to grade 4 (very severe with bony contact throughout the entire joint surface).

### MRI Evaluation

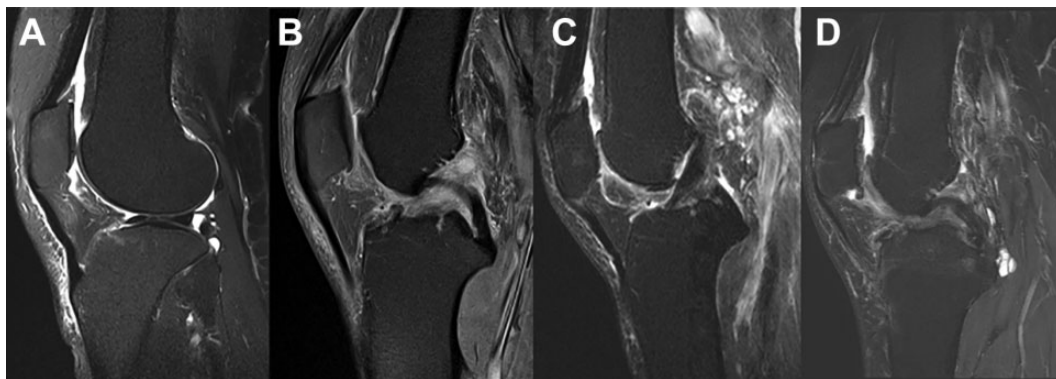
MRI was performed preoperatively and at a mean of  $19.4 \pm 6.3$  months after surgery. Essentially, 3.0-T MRI was performed to evaluate preoperative osteophytes, preoperative and postoperative bone marrow lesions (BMLs), and cartilage loss in the weightbearing portion of the femur. MRI was performed in the medial, lateral, and patellofemoral compartments of the knee. Standard non-fat suppressed short T1-weighted scans were used to evaluate osteophyte

formation in the lateral and patellofemoral compartments. The MRI Osteoarthritis Knee Score (MOAKS) classification system was developed to evaluate degenerative changes in the knee with the aid of MRI, including the location and severity of osteophyte formation, BMLs, and cartilage loss.<sup>9</sup> The MOAKS classification system of osteophytes has grades ranging from 0 (none) to 3 (large) (Figures 3 and 4). The largest osteophyte within a given location was scored.<sup>9</sup> Cartilage loss was classified as grade 0 (none), grade 1 (<10% of the region of the cartilage surface area), grade 2 (10%-75% of the region of the cartilage surface area), and grade 3 (>75% of the region of the cartilage surface area). The largest area of cartilage loss was scored.

The grades of cartilage loss on preoperative and postoperative MRI were compared. Osteophyte formation in the lateral and patellofemoral compartments was graded using



**Figure 3.** MRI Osteoarthritis Knee Score (MOAKS) grade of osteophytes in the lateral compartment: (A) grade 0 (none), (B) grade 1 (small), (C) grade 2 (medium), and (D) grade 3 (large). MRI, magnetic resonance imaging.



**Figure 4.** MRI Osteoarthritis Knee Score (MOAKS) grade of osteophytes in the patellofemoral compartment: (A) grade 0 (none), (B) grade 1 (small), (C) grade 2 (medium), and (D) grade 3 (large). MRI, magnetic resonance imaging.

MRI scans and radiographs. The cartilage status was compared between preoperative and last follow-up MRI.

#### Arthroscopic Evaluation

The macroscopic cartilage status was evaluated during index arthroscopic surgery and second-look arthroscopic surgery at the time of plate removal, which was at a mean of  $20.0 \pm 6.1$  months after surgery. The arthroscopic assessment was performed in the medial, lateral, and patellofemoral compartments of the knee. The International Cartilage Repair Society (ICRS) grade was used to evaluate the cartilage status<sup>18,24</sup>: grade 0 (no cartilage loss), grade 1 (superficial crack), grade 2 (<50% thickness of cartilage loss), grade 3 (>50% thickness of cartilage loss), and grade 4 (full thickness of cartilage loss). The change in grades between the index and second-look arthroscopic procedures was compared.

#### Clinical Evaluation

Clinical outcomes were assessed preoperatively and at the final follow-up, at a mean of  $40.5 \pm 13.0$  months after surgery. The American Knee Society (AKS) score (knee and

function scores) was used to assess the degree of OA in the knee. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to assess 5 items on pain, 2 items on stiffness, and 17 items on physical function. The total score for the 24 items was used to evaluate the degree of degeneration in the joints based on the clinical results. In addition, we evaluated 8 health concepts, including body function, pain, role limitations, role limitations because of emotional problems, and social function, using the 36-item Short Form Health Survey (SF-36).

#### Surgical Technique

All surgical procedures were performed by a single senior surgeon (Y.S.L.). An approximately 5-cm incision was created longitudinally at the anteromedial aspect of the proximal tibia. Thereafter, the subcutaneous area was dissected. The superior border of the pes anserinus and the anterior border of the medial collateral ligament were mobilized from the tibia and released using a periosteal elevator. A protective cutting system (Tradimedics and Corentec) was used for the advancement of posterior osteotomy to the proximal tibiofibular joint area with the help of intraoperative fluoroscopy.<sup>17</sup> Horizontal osteotomy was

performed using guiding pins, taking great care to preserve the lateral cortex. Finally, additional biplanar anterior osteotomy, extending proximally with the Lobenhoffer technique, was performed after removing the protective cutting system.<sup>5,11</sup> Distraction was performed gradually at the most posterior gap until the target mechanical axis was obtained.<sup>15</sup> Usually, the target point was around 62.5% of the WBL ratio and was adjusted from 55% to 65% according to the status of the medial compartment. If the medial compartment showed severe degeneration, it was shifted to a larger correction of approximately 65%. The posterior slope was controlled by balancing the anterior and posterior gaps. Stable locking plate fixation was performed at the osteotomy site. Bone grafting was performed according to our protocol that was randomly selected using allograft bone chips, synthetic bone chips, or no bone graft. Finally, the presence of lateral hinge fractures was carefully examined under intraoperative fluoroscopy.

Postoperatively, on the first day after surgery, the drain was removed, and on the third postoperative day, isometric quadriceps exercises, active ankle exercises, and straight-leg raises were started. The patients were allowed to move their knee from 0° to 100° after 2 weeks. The final correction and degree of limb alignment were confirmed using full-length standing radiographs after 2 weeks. Toe-touch weightbearing began at 2 weeks after surgery, followed by partial weightbearing for the next 4 weeks. Full weightbearing was allowed 6 weeks after the radiographic evaluation for bone consolidation at the osteotomy site. Standardized full-length standing hip-to-ankle, standing knee anteroposterior, and knee lateral digital radiographs were obtained before surgery and at 2 weeks, 4 weeks, 8 weeks, 3 months, 6 months, and 12 months after surgery. The patients were then evaluated annually. Second-look arthroscopic surgery was carried out at the time of metal removal.

## Statistical Analysis

All statistical analyses were performed using SPSS version 22.0 (IBM). Data are presented as means and standard deviations for continuous variables. The differences in the quantitative variables (ie, age, body mass index [BMI], WBL ratio, HKA angle, correction angle, and clinical scores) were analyzed using the Student *t* test and Mann-Whitney *U* test. To compare the qualitative variables (ie, sex and difference in postoperative cartilage loss on MRI and second-look arthroscopic surgery), the Pearson chi-square test or Fisher exact test was used. The McNemar-Bowker symmetry test was performed to assess the difference in OARSI and MOAKS grades. The kappa coefficient was used to evaluate the reliability of the radiographic evaluation. The kappa values ranged from 0 to 1, with 1 indicating perfect agreement between the 2 observers. The statistical significance level was set at *P* values of <.05.

## RESULTS

The mean age and BMI of the patients at the time of surgery were  $56.6 \pm 5.7$  years and  $27.0 \pm 3.5$  kg/m<sup>2</sup>,

respectively. The mean follow-up for the MRI, arthroscopic, and clinical evaluations were at  $19.4 \pm 6.3$ ,  $20.0 \pm 6.1$ , and  $40.5 \pm 13.0$  months, respectively. Among the 121 knees, 13 knees did not have postoperative MRI scans, and 12 knees did not have arthroscopic images. However, all knees had at least 1 postoperative MRI scan or arthroscopic image. OARSI, MOAKS, and ICRS grading by radiographs, MRI scans, and arthroscopic images was performed by 2 sports medicine fellows (D.H.K., S.C.K.) with no affiliation with the operative procedure. The kappa values for interrater agreement on radiographs, MRI scans, and arthroscopic images were 0.859 and 0.867, 0.858 and 0.865, and 0.856 and 0.864, respectively. The reliabilities were good.

The patients were categorized into 4 groups according to the preoperative OARSI and MOAKS grades. No degenerative changes in the lateral and patellofemoral compartments of knees (group I) were identified in 51.2% of cases (62 knees). Asymptomatic degenerative changes only in the lateral compartment (group II: OARSI grades 1-3 and MOAKS grades 1-3) were identified in 15.7% of cases (19 knees), changes only in the patellofemoral compartment (group III: OARSI grades 1-3 and MOAKS grades 1-3) were identified in 10.7% of cases (13 knees), and changes in both the lateral and the patellofemoral compartments (group IV) were identified in 22.3% of cases (27 knees). For joint space narrowing of the lateral and patellofemoral compartments, only 7.4% (9 knees) and 6.6% (8 knees) were categorized as grades 1 and 2, respectively. Therefore, we did not consider joint space narrowing in categorizing the patients. There was no significant difference between the OARSI and MOAKS grades (*P* = .062).

Preoperative demographics are outlined in Table 1. The patients in group II were younger than those in group I (*P* = .035); conversely, group II had a higher BMI than group I (*P* = .013). Postoperative clinical scores are outlined in Table 2. The postoperative HKA angle, WBL ratio, and clinical scores had no significant differences between group I and the other groups.

## MRI Assessment

In the medial compartment, 96.4%, 94.1%, 90.0%, and 94.5% of knees showed improvements in the MOAKS grade among groups I, II, III, and IV, respectively (Figure 5A). There was no significant difference in the improvement among all 4 groups (*P* = .813). In the medial compartment, 72.6% had preoperative BMLs, and 91.7% among them showed improvement in the MOAKS grade. In the lateral compartment, 7.3%, 11.8%, 18.2%, and 18.5% of knees demonstrated declines in the MOAKS grade among groups I, II, III, and IV, respectively (Figure 5B). In the patellofemoral compartment, 7.3%, 17.6%, 9.1%, and 18.5% of knees demonstrated declines in the MOAKS grade, respectively (Figure 5C). There was no significant difference in decline in the lateral and patellofemoral compartments among all 4 groups (*P* = .649 and .421, respectively).

TABLE 1  
Preoperative Demographics and Clinical Scores<sup>a</sup>

|                        | Group I     | Group II    | <i>P</i> Value <sup>b</sup> | Group III   | <i>P</i> Value <sup>b</sup> | Group IV    | <i>P</i> Value <sup>b</sup> |
|------------------------|-------------|-------------|-----------------------------|-------------|-----------------------------|-------------|-----------------------------|
| Age, y                 | 57.3 ± 5.4  | 53.9 ± 7.4  | .035 <sup>c</sup>           | 55.9 ± 5.0  | .309                        | 57.2 ± 4.8  | .499                        |
| Sex, M/F, n            | 24/38       | 4/15        | .157                        | 6/7         | .618                        | 6/21        | .130                        |
| BMI, kg/m <sup>2</sup> | 26.1 ± 2.9  | 28.1 ± 3.9  | .013 <sup>c</sup>           | 28.5 ± 4.7  | .147                        | 27.3 ± 3.7  | .356                        |
| HKA angle (varus), deg | 5.3 ± 3.4   | 4.0 ± 3.8   | .308                        | 4.0 ± 3.4   | .231                        | 5.4 ± 3.6   | .979                        |
| WBL ratio, %           | 17.9 ± 14.3 | 15.2 ± 12.3 | .318                        | 25.0 ± 10.0 | .073                        | 13.8 ± 11.1 | .116                        |
| AKS knee               | 47.3 ± 15.6 | 53.9 ± 12.3 | .064                        | 48.5 ± 17.2 | .683                        | 52.1 ± 14.9 | .057                        |
| AKS function           | 57.1 ± 11.8 | 61.8 ± 9.3  | .137                        | 59.3 ± 14.6 | .975                        | 57.1 ± 11.9 | .682                        |
| WOMAC pain             | 8.5 ± 3.5   | 7.4 ± 3.0   | .271                        | 8.1 ± 3.3   | .729                        | 8.3 ± 3.8   | .575                        |
| WOMAC stiffness        | 3.6 ± 2.0   | 2.9 ± 2.3   | .236                        | 5.3 ± 6.2   | .691                        | 3.3 ± 2.1   | .554                        |
| WOMAC function         | 25.0 ± 9.3  | 23.9 ± 7.8  | .564                        | 22.9 ± 8.2  | .776                        | 25.5 ± 12.4 | .845                        |
| SF-36 PCS              | 37.9 ± 6.6  | 37.1 ± 6.4  | .907                        | 35.9 ± 8.1  | .317                        | 37.0 ± 8.0  | .713                        |
| SF-36 MCS              | 42.8 ± 10.3 | 44.2 ± 13.1 | .731                        | 43.9 ± 6.8  | .759                        | 45.8 ± 10.0 | .165                        |

<sup>a</sup>Data are shown as mean ± SD unless otherwise indicated. AKS, American Knee Society; BMI, body mass index; F, female; HKA, hip-knee-ankle; M, male; MCS, mental component summary; PCS, physical component summary; SF-36, 36-item Short Form Health Survey; WBL, weightbearing line; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

<sup>b</sup>*P* value in the fourth column is the comparison of Group I & II; *P* value in the sixth column is the comparison of Group I & III; and *P* value in the eighth column is the comparison of Group I & IV.

<sup>c</sup>Statistically significant difference versus group I (*P* < .05).

TABLE 2  
Postoperative Clinical Scores<sup>a</sup>

|                         | Group I     | Group II    | <i>P</i> Value | Group III   | <i>P</i> Value | Group IV    | <i>P</i> Value |
|-------------------------|-------------|-------------|----------------|-------------|----------------|-------------|----------------|
| HKA angle (valgus), deg | 0.2 ± 2.6   | 0.3 ± 2.8   | .982           | -0.4 ± 3.0  | .882           | -0.4 ± 3.1  | .441           |
| WBL ratio, %            | 52.7 ± 10.8 | 52.9 ± 13.8 | .348           | 59.9 ± 12.2 | .069           | 56.2 ± 11.1 | .061           |
| AKS knee                | 92.7 ± 6.9  | 92.0 ± 8.2  | .976           | 93.6 ± 5.0  | .906           | 92.9 ± 7.5  | .811           |
| AKS function            | 90.5 ± 8.9  | 85.3 ± 10.7 | .076           | 90.0 ± 10.0 | .913           | 89.5 ± 9.1  | .576           |
| WOMAC pain              | 1.1 ± 1.3   | 1.5 ± 1.8   | .586           | 0.7 ± 0.8   | .492           | 1.4 ± 1.5   | .585           |
| WOMAC stiffness         | 0.9 ± 1.4   | 1.0 ± 0.9   | .259           | 0.5 ± 0.8   | .280           | 1.0 ± 1.9   | .590           |
| WOMAC function          | 5.6 ± 4.5   | 6.7 ± 5.9   | .698           | 4.3 ± 2.4   | .592           | 6.0 ± 4.6   | .788           |
| SF-36 PCS               | 85.8 ± 10.7 | 83.1 ± 12.1 | .294           | 87.5 ± 9.5  | .563           | 84.2 ± 12.0 | .742           |
| SF-36 MCS               | 88.6 ± 9.0  | 85.8 ± 11.2 | .489           | 86.5 ± 11.5 | .516           | 87.4 ± 11.2 | .857           |

<sup>a</sup>Data are shown as mean ± SD unless otherwise indicated. AKS, American Knee Society; HKA, hip-knee-ankle; MCS, mental component summary; PCS, physical component summary; SF-36, 36-item Short Form Health Survey; WBL, weightbearing line; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

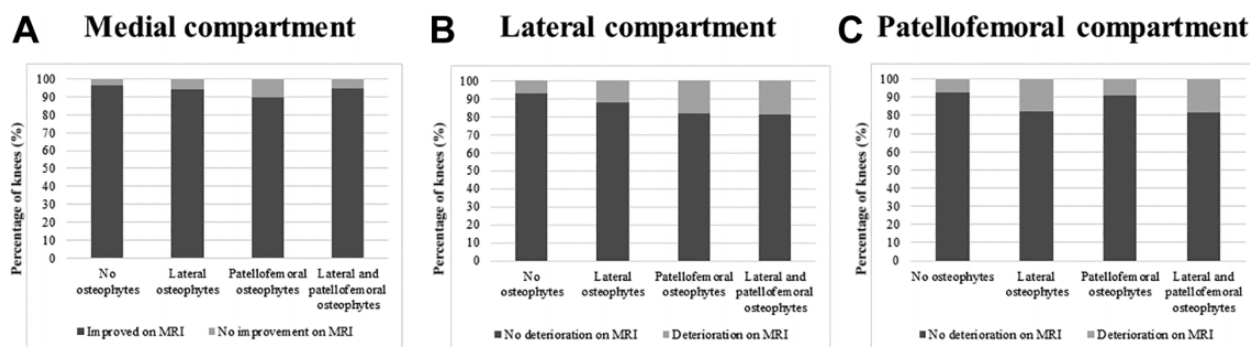
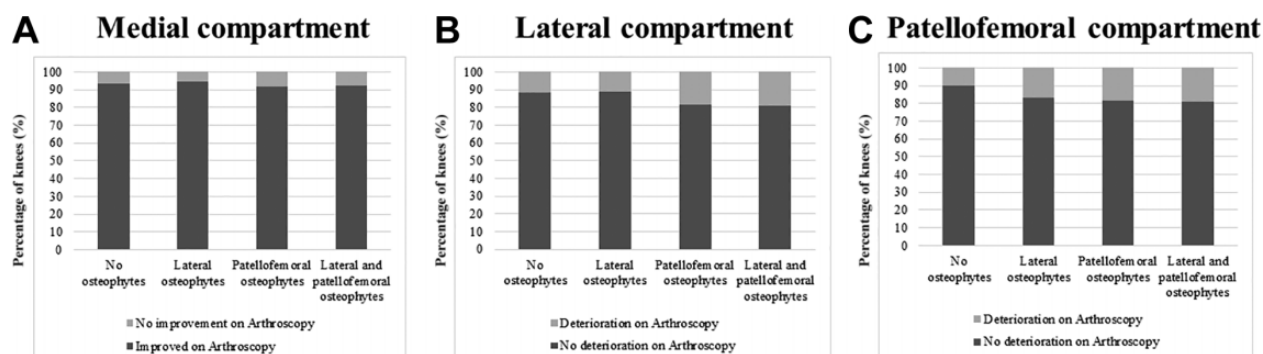


Figure 5. Comparison of MOAKS grade improvement and deterioration from preoperative to MRI follow-up among the study groups in the (A) medial, (B) lateral, and (C) patellofemoral compartments. MRI, magnetic resonance imaging; MOAKS, MRI Osteoarthritis Knee Score.



**Figure 6.** Comparison of ICRS grade improvement and deterioration from preoperative to second-look arthroscopic surgery among the study groups in the (A) medial, (B) lateral, and (C) patellofemoral compartments. ICRS, International Cartilage Repair Society.

### Arthroscopic Assessment

In the medial compartment, 93.3%, 94.7%, 91.7%, and 92.3% of knees demonstrated improvements in the ICRS grade among groups I, II, III, and IV, respectively (Figure 6A). There was no significant difference in improvement among all 4 groups ( $P = .985$ ). In the lateral compartment, 11.8%, 11.1%, 18.2%, and 19.2%, respectively, showed declines in the ICRS grade (Figure 6B), and in the patellofemoral compartment, 9.8%, 16.7%, 18.2%, and 19.2%, respectively, showed declines in the ICRS grade (Figure 6C). There was no significant difference in decline in the lateral and patellofemoral compartments among all 4 groups ( $P = .927$  and  $.676$ , respectively).

### DISCUSSION

The principal findings of this study are as follows: The presence of mild lateral and patellofemoral degenerative changes did not affect the clinical, MRI, or arthroscopic outcomes of OWHTO in the midterm postoperative period. Asymptomatic mild lateral or patellofemoral degenerative changes were observed in one-quarter of the patients in our series and both mild lateral and patellofemoral degenerative changes in 22.3%. There was no significant difference in the pre- versus postoperative HKA angles, WBL ratios, and clinical scores among the groups that were categorized according to osteophyte formation. Further, there was no significant difference in the improvement of MOAKS and ICRS grades in the medial compartment according to the MRI and arthroscopic assessments, and there was no significant difference in the decline of MOAKS and ICRS grades in the lateral and patellofemoral compartments. Therefore, our hypothesis was verified.

We used several grading systems to observe and classify mild degenerative changes in the medial, lateral, and patellofemoral compartments. The OARSI grade was used to assess osteophyte formation and joint space narrowing in the medial and lateral compartments. Patellofemoral joint space narrowing was classified according to the system by Merchant et al.<sup>19</sup> However, for lateral and patellofemoral joint space narrowing, most of the patients showed grade

0 or 1 and grade 1 or 2, respectively. Along with the OARSI grade, we used the MOAKS grade to identify osteophytes in the lateral and patellofemoral compartments. Osteophytes were identified more specifically with the MOAKS grade, as the femur was subdivided into 6 subregions.<sup>9</sup>

There have been some clinical studies conducted on cartilage lesions in the lateral compartment.<sup>21,22</sup> Niemeyer et al<sup>22</sup> reported that the clinical outcomes of patients with partial-thickness cartilage lesions in the lateral compartment after OWHTO were not different from those of patients with completely intact cartilage in the lateral compartment. The follow-up period of their study was about 36 months. Moon et al<sup>21</sup> reported that the presence of ICRS grade 2 or 3 cartilage lesions in the lateral compartment did not affect the outcomes of OWHTO after roughly 23 months of follow-up. However, these studies only evaluated outcomes according to the cartilage status of the lateral compartment. In the current study, we examined the status of the lateral and patellofemoral compartments and evaluated plain radiographs, MRI scans, and arthroscopic images altogether.

In our study, we attempted to observe and classify mild degenerative changes in the lateral and patellofemoral compartments. For proper verification and improvement in the validation of outcomes, we used a variety of assessment tools, such as the AKS score, WOMAC, and SF-36. In addition to the clinical outcomes, we used preoperative and postoperative MRI and arthroscopic surgery as objective assessment tools. In the MRI and arthroscopic assessments, there was no significant difference in the percentage of knees with improvements in the medial compartment or knees with declines in the lateral and patellofemoral compartments among the 4 groups. We compared all 4 groups; therefore, the effect of osteophyte formation in both the lateral and the patellofemoral compartments was nonsignificant on the MRI, arthroscopic, and clinical outcomes of OWHTO. In the lateral and patellofemoral compartments, group IV (asymptomatic degenerative changes in both compartments) had the largest percentage of knees with declines in the MOAKS grade (18.5%) as well as the largest percentage with declines in the ICRS grade (19.2%), although these findings were not statistically significant compared with the other groups.



The findings in our study are presented in relatively short term period, and OWHTO may slow disease progression in the medial compartment but not necessarily in the other knee compartments. Moreover, the results of OWHTO can decline with time, and pre-existing lateral and patellofemoral OA can be aggravated. We view OWHTO as a bridging procedure in younger patients and recognize that many of these patients will eventually go on to total knee arthroplasty. However, a longer observation is necessary to assess whether lateral and patellofemoral mild OA affect the outcomes of OWHTO. Therefore, we are planning to perform serial MRI at regular intervals for this purpose.

We only enrolled asymptomatic patients with radiographic evidence of medial compartmental OA with minimal degenerative changes in the lateral or patellofemoral compartment. We asked our patients to point out the location of pain in the knee joint. Additionally, we checked medial and lateral joint-line tenderness. The patients who were enrolled in this study did not have any symptoms in the lateral or anterior knee joints. Some patients noted anterior knee pain in the early postoperative period. However, it was transient only in the early postoperative period, and none of the patients indicated extension weakness or limitations of motion at the final follow-up. Therefore, we did not perform surrogate measurements for patellofemoral symptoms.<sup>16</sup> Most of our patients did not report lateral compartment symptoms either before or after surgery. However, some patients had pain in the lateral hinge area transiently after surgery. The pain disappeared as the opening gap united. Preoperative lateral and patellofemoral degenerative changes were quite mild, with osteophyte formation and signal changes up to KL grade 1. Moreover, the status of the lateral and patellofemoral compartments did not cause symptoms preoperatively or translate to significant lateral or patellofemoral joint space narrowing in our patients.

HTO was introduced as a treatment along with UKA because they share some indications, but they are different procedures. Several studies on UKA are similar to our research, even though UKA usually results in some residual varus, but OWHTO results in overcorrection into valgus. Hamilton et al<sup>7</sup> highlighted the importance of an appropriate preoperative assessment of the lateral compartment and reported in their 15-year follow-up study that lateral osteophytes do not compromise the long-term functional outcome or implant survival of medial UKA. Adams et al<sup>1</sup> and Xu et al<sup>26</sup> studied medial UKA and the preoperative status of the patellofemoral compartment. Adams et al reported that the functional outcomes of fixed-bearing medial UKA are not adversely affected by the presence of patellofemoral chondromalacia. Xu et al reported that neither mild to moderate degrees of patellofemoral joint degeneration nor the location of preoperative pain compromised the short-term outcomes of medial UKA.

This study has several limitations. First, the study was nonrandomized and retrospective, which could be associated with a risk of bias in selection and evaluation. Second, the follow-up period was relatively short. To confirm the effect of mild degenerative changes in the lateral and patellofemoral compartments on clinical outcomes, a longer and

serial follow-up would be needed. Especially in group IV with asymptomatic degenerative changes in both the lateral and the patellofemoral compartments, a decline was observed in a higher percentage of knees compared with the groups with asymptomatic degenerative changes in the isolated lateral or patellofemoral compartment. Although this difference was not significant between groups, it could imply that a longer and serial assessment is needed in this group. Third, because we divided the patients into 4 groups, the sample in the patellofemoral compartment group was relatively small compared with those in the other groups.

## CONCLUSION

The presence of mild lateral or patellofemoral degenerative changes did not affect the MRI, arthroscopic, and clinical outcomes of OWHTO. However, long-term observations are necessary to draw definitive conclusions about whether OWHTO can be indicated in such patients without harmful effects.

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