Second-Look Arthroscopic Assessment of Cartilage Regeneration After Medial Opening-Wedge High Tibial Osteotomy

Woon-Hwa Jung, M.D., Ryohei Takeuchi, M.D., Chung-Woo Chun, M.D., Jung-Su Lee, M.D., Jae-Hun Ha, P.A., Ji-Hyae Kim, P.A., and Jae-Heon Jeong, M.D.

Purpose: The purposes of this study were to evaluate regeneration of the articular cartilage after medial opening-wedge high tibial osteotomy for knees with medial-compartment osteoarthritis and to assess the clinical outcome and cartilage regeneration according to the postoperative limb alignment at 2 years postoperatively. Methods: The study involved 159 knees in 159 patients. For evaluation of cartilage degeneration, the International Cartilage Repair Society grading system was used for arthroscopic grading on initial arthroscopy during high tibial osteotomy. The patients underwent a second-look arthroscopic evaluation of the articular cartilage at the time of removal of the plate, an average of 2 years after the initial osteotomy. For evaluation of cartilage regeneration, the articular cartilage was classified into 2 stages as no regenerative change (grade 1) or white scattering with fibrocartilage, partial coverage with fibrocartilage, or even coverage with fibrocartilage (grade 2) on second-look arthroscopy. Maturation of the cartilage regeneration was defined as even coverage with fibrocartilage. “Immaturity” of the cartilage regeneration was defined as white scattering with fibrocartilage or partial coverage with fibrocartilage. Clinical evaluations were performed by use of Knee Society scores preoperatively and at 2 years postoperatively. We divided the knees into 3 groups according to the postoperative limb alignment. Group A comprised knees with a mechanical tibiofemoral angle of 0° or less. Group B comprised knees with a mechanical tibiofemoral angle greater than 0° and less than 6°. Group C comprised knees with a mechanical tibiofemoral angle of 6° or greater. Results: Grade 2 regeneration was achieved in the medial femoral condyle articular cartilage in 92% of knees and in the medial tibial plateau articular cartilage in 69% of knees. Maturation of the cartilage regeneration was found in the medial femoral condyle articular cartilage in 4% of knees and in the medial tibial plateau articular cartilage in 1% of knees. At follow-up, no significant differences were seen between clinical outcomes and initial cartilage degeneration \((P = .338)\) or cartilage regeneration \((P = .699)\). Regeneration of the medial femoral condyle articular cartilage was found in 75% of group A knees, 95% of group B knees, and 92% of group C knees. Significant differences were seen between cartilage regeneration and clinical outcomes \((P = .001)\), as well as postoperative limb alignment \((P = .018)\). Clinical and regeneration results were better in group B than in groups A and C. Conclusions: The degenerated cartilage of the medial femoral condyle and medial tibial plateau could be partially or entirely covered by newly regenerated cartilage at 2 years after adequate correction of varus deformity by medial opening-wedge high tibial osteotomy without cartilage regeneration strategies. Level of Evidence: Level IV, therapeutic case series.
The purposes of this study were to evaluate regeneration of the articular cartilage after a medial opening-wedge HTO for knees with medial-compartment osteoarthritis and to assess the clinical outcome and regeneration of the articular cartilage according to the postoperative limb alignment at follow-up 2 years postoperatively. We hypothesized that there would be cartilage regeneration after HTO and a correlation between the clinical outcome and regeneration of the articular cartilage, as well as postoperative limb alignment, 2 years postoperatively.

**Methods**

This study was a retrospective, nonrandomized, sequential review. Between January 2009 and January 2010, 182 patients underwent HTO for medial-compartment osteoarthritis of the knee at the Department of Orthopedic Surgery, Murup Hospital, Gyeongnam, South Korea. Inclusion criteria for HTO were as follows: symptomatic medial osteoarthritis or articular cartilage lesions of the knee joint in active patients, varus malalignment (minimum of 10 mm of medialization of the weight-bearing axis from the anatomic center of the knee or 3° of varus malalignment), and a lateral joint compartment that was intact or whose cartilage lesions had an International Cartilage Repair Society (ICRS) grade of less than 1 with failure of conservative treatment for 3 months. Exclusion criteria were active infection of the knee, severe osteoarthritis of the patellofemoral joint, a lateral femorotibial angle of 190° (10° anatomic varus alignment) or greater, and a flexion contracture of greater than 15°. We also excluded patients with varus/valgus instability of greater than 10° on a stress view obtained with a Telos device (Telos, Marburg, Germany) and those aged 60 years or older with anterior cruciate ligament insufficiency. Of the 182 patients, 23 were lost to follow-up. We performed follow-up evaluations in 159 cases (Table 1). All of these patients underwent second-look arthroscopy during plate and screw removal. Postoperative complications were analyzed retrospectively by use of patient charts and were defined as nonunion, correction failure (revarization or overcorrection), and infection.

**Surgical Procedure and Postoperative Rehabilitation**

All patients underwent an arthroscopic examination at the time of HTO. However, drilling of a degenerative ulcer or shaving of the articular cartilage was not performed in any case. After arthroscopy, a medial opening-wedge HTO was performed with a TomoFix plate (Synthes, Solothurn, Switzerland). A porous β-tricalcium phosphate wedge (semicircular chronOS; Synthes) was inserted in the osteotomy gap. The TomoFix plate was then inserted into a subcutaneous tunnel formed on the medial side of the tibia and fixed in place with locking screws with minimal invasiveness (Video 1, available at www.arthroscopyjournal.org).

The day after surgery, active and passive range-of-motion exercises with continuous passive motion and muscle strengthening were commenced. Range-of-motion exercises with continuous passive motion were continued until a maximum flexion angle of 130° or more was obtained within 3 weeks of surgery. Patients were allowed to begin partial weight-bearing exercises with crutches or a walker 1 day after surgery, and they could walk with full weight bearing with a cane 6 weeks after HTO.

**Preoperative Planning**

The Mikulicz mechanical axis was used to evaluate lower limb alignment and to determine the amount of correction needed. A line was drawn from the center of the femoral head to the center of the superior articular surface of the talus on an anteroposterior full-leg length radiograph taken with the patient standing on the affected leg and with the knee joint in full extension. The point at which the mechanical axis passed the level of the tibial articular surface was defined as the Fujisawa point. The location was expressed as a percentage of the width of the tibial condyle. We defined the point at the medial edge of the tibial condyle as 0% and the point at the lateral edge as 100%. We carried out HTO to pass the mechanical axis at 65% from the medial edge. All radiographs had a magnification marker for preoperative planning and were in digital format and magnified 100×.

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**Table 1. Patient Demographic Characteristics and Preoperative and Postoperative Findings**

<table>
<thead>
<tr>
<th>Data</th>
<th>Postoperative Findings</th>
<th>Preoperative Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>60.2 ± 6.8 (41-75)</td>
<td></td>
</tr>
<tr>
<td>Gender (male-female)</td>
<td>14:145</td>
<td></td>
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<tr>
<td>BMI</td>
<td>25.4 ± 2.8 (16.8-37.2)</td>
<td></td>
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<tr>
<td>Time interval from initial operation to removal operation (mo)</td>
<td>18.9 ± 5.6 (7-35)</td>
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<tr>
<td>Preoperative flexion contracture (°)</td>
<td>1.1 ± 3.4 (0-20)</td>
<td></td>
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<tr>
<td>Preoperative further flexion (°)</td>
<td>142.3 ± 7.0 (90-150)</td>
<td></td>
</tr>
<tr>
<td>PreKSS</td>
<td>68.5 ± 11.9 (30-90)</td>
<td></td>
</tr>
<tr>
<td>PreKSSF</td>
<td>62.3 ± 11.4 (0-90)</td>
<td></td>
</tr>
<tr>
<td>PreTFA (°)</td>
<td>187.8 ± 4.3 (183.2-192.3)</td>
<td></td>
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<tr>
<td>Postoperative flexion contracture (°)</td>
<td>0.4 ± 2.0 (0-15)</td>
<td></td>
</tr>
<tr>
<td>Postoperative further flexion (°)</td>
<td>144.2 ± 3.0 (120-150)</td>
<td></td>
</tr>
<tr>
<td>PostKSS</td>
<td>92.5 ± 7.1 (56-100)</td>
<td></td>
</tr>
<tr>
<td>PostKSSF</td>
<td>90.4 ± 9.0 (60-100)</td>
<td></td>
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<tr>
<td>PostTFA (°)</td>
<td>177.1 ± 2.0 (171.3-184.5)</td>
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</table>

BMI, body mass index; PostKSS, postoperative Knee Society knee score; PostKSSF, postoperative Knee Society function score; PostTFA, postoperative mechanical tibiofemoral angle; PreKSS, preoperative Knee Society knee score; PreKSSF, preoperative Knee Society function score; PreTFA, preoperative mechanical tibiofemoral angle.
Clinical Evaluation
Clinical examinations of the knee joints in our patient cohort consisted of both subjective and objective parameters that were recorded and documented by use of the Knee Society knee score and function score.

Radiologic Evaluation
The radiologic evaluation included the mechanical tibiofemoral angle (negative values indicate varus deviation and positive values indicate valgus deviation) preoperatively and at 2 years postoperatively. We evaluated anteroposterior, lateral, and full-limb weight-bearing views preoperatively and at follow-up 2 years postoperatively, taking care to ensure neutral limb rotational positioning in all patients enrolled in the study. All radiographs had a magnification marker for preoperative planning and were in digital format and magnified 100×.

Arthroscopic Evaluation
The medial femoral condyle and tibial plateau articular cartilage was evaluated by arthroscopy before and about 24 months after HTO. For evaluation of cartilage degeneration, degeneration of the articular cartilage at the time of the initial HTO was graded according to the ICRS grading system.30 In brief, according to the ICRS grading system, superficial lesions and superficial fissures and cracks are considered grade 1 cartilage defects whereas lesions extending down to less than 50% of the cartilage depth are considered grade 2 defects. Grade 3 defects are defined as those extending down to more than 50% but not involving the subchondral bone. Defects involving the subchondral bone are classified as grade 4 defects according to the ICRS classification.

The patients underwent a second-look arthroscopic evaluation of the articular cartilage at the time of removal of the plate in 159 cases (87%); this evaluation was not performed in the 23 cases lost to follow-up. The medial femoral condyle and tibial articular cartilage was evaluated during second-look arthroscopy according to regeneration grade and maturation grade.23,28 For evaluation of cartilage regeneration, the articular cartilage was classified into 2 stages as no regenerative change (grade 1) or white scattering with fibrocartilage, partial coverage with fibrocartilage, or even coverage with fibrocartilage (grade 2).27 Maturation of the cartilage regeneration was defined as even coverage with fibrocartilage. “Immaturation” of the cartilage regeneration was defined as white scattering with fibrocartilage or partial coverage with fibrocartilage.28

Subgroup Analysis
We evaluated regeneration of the medial femoral condyle and medial tibial plateau cartilage according to the articular cartilage lesion grade during HTO. We assessed the clinical outcome according to the articular cartilage regeneration grade. We divided the knees into 3 groups according to the postoperative limb alignment.21,31 Group A comprised knees with a mechanical tibiofemoral angle of 0° or less. Group B comprised knees with a mechanical tibiofemoral angle greater than 0° and less than 6°. Group C comprised knees with a mechanical tibiofemoral angle of 6° or greater. We assessed the clinical outcome and cartilage regeneration according to the postoperative limb alignment. In addition, we evaluated the clinical outcome and cartilage regeneration according to age, gender, and body mass index.

Statistical Analysis
Two blinded reviewers independently reviewed the patients’ radiographs on 2 separate occasions. There was no communication between the 2 reviewers. Radiographic data were presented in random order, and the order was changed in the 2 different sessions.

We assessed interobserver and intraobserver reliabilities for the 2 measured parameters—mechanical tibiofemoral angle and regeneration grade—using intraclass and interclass correlation coefficients. Intraclass and interclass correlation coefficients were interpreted as follows: 0.20 or less, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and greater than 0.80, almost perfect agreement.32 Differences in radiologic measurements and comparisons between the preoperative and postoperative Knee Society scores in each group were determined by a paired t test. The medial femoral condyle and tibial articular cartilage was evaluated during second-look arthroscopy according to regeneration grade and maturation grade. All data for regeneration of the articular cartilage were statistically analyzed with analysis of variance. Data were analyzed statistically with SPSS software, version 12.0 (SPSS, Chicago, IL). For all tests, P < .05 indicated a significant difference.

Results
Clinical and Radiographic Results
We evaluated 14 knees in 14 men and 145 knees in 145 women, comprising 159 knees in 159 patients. Approximately 24.9 months after surgery (range, 22 to 26 months), the patients underwent second-look arthroscopic examinations. The mean age (± standard deviation) of the patients at the time of second-look arthroscopy was 60.2 ± 6.8 years (range, 41 to 75 years). The mean Knee Society knee score improved significantly from 68.5 ± 11.9 before the operation to 92.5 ± 7.1 at follow-up 2 years postoperatively (P = .001). The mean Knee Society function score improved significantly from 62.3 ± 11.4 before the operation to
90.4 ± 9.0 at follow-up 2 years postoperatively (P = .001). The mean mechanical tibiofemoral angle was −4.8° ± 2.6° preoperatively and 2.9° ± 2.0° at follow-up 2 years postoperatively (Table 1). Correction failure was found in 16 cases with revarization and 10 cases with overcorrection. There were no cases of nonunion or infection in this study.

Cartilage Regeneration
At second-look arthroscopic examination, no regeneration of the articular cartilage (grade 1) was found in 8% of knees (12 of 159) and grade 2 regeneration was found in 92% of knees (147 of 159). On the other hand, immaturation was found in 96% of knees (153 of 159) and maturation was found in 4% of knees (6 of 159).

At initial arthroscopy, 31 knees (20%) had grade 3 medial femoral condyle articular cartilage findings, 118 knees (74%) had grade 2 findings, and 10 knees (6%) had grade 1 findings. Of the 31 knees with grade 3 articular cartilage degeneration (ICRS grade 3) preoperatively, 18 (58%) had partial coverage with fibrocartilage (grade 2, immature regeneration), 11 (35%) had white scattering with fibrocartilage (grade 2, immature regeneration), and 2 (7%) showed no regenerative change (grade 1). Furthermore, deterioration of the cartilage was observed in 4 cases (3%). At initial arthroscopy, 28 knees (17%) had grade 3 medial tibial plateau articular cartilage findings, 66 knees (42%) had grade 2 findings, and 65 knees (41%) had grade 1 findings. Of the 28 knees with grade 3 articular cartilage preoperatively, 1 (4%) had even coverage with fibrocartilage (grade 2, mature regeneration), 11 (39%) had partial coverage with fibrocartilage (grade 2, immature regeneration), and 14 (50%) had white scattering with fibrocartilage (grade 2, immature regeneration). No regenerative change (grade 1) was found in 2 knees (7%). Furthermore, deterioration of the cartilage was observed in 3 cases (2%). Less than half-thickness cartilage damage (ICRS grade 2) at the time of HTO showed improvement to partial coverage with fibrocartilage (grade 2, immature regeneration) at follow-up in 72 of 118 knees (61%) (Fig 1). As a result, the cartilage on the femorotibial joint surfaces that had been slightly injured at the time of HTO had not yet completely recovered at follow-up. No significant differences were observed at the time of second-look arthroscopy in cartilage regeneration according to the grade of degeneration during HTO (P = .338). No significant differences were observed at the time of second-look arthroscopy in clinical outcome according to the grade of regeneration (P = .699).

Regeneration of Articular Cartilage and Clinical Outcome According to Postoperative Limb Alignment
In group A (mechanical tibiofemoral angle ≤0°, revarization group), the mean Knee Society knee score improved significantly from 64.6 ± 11.2 before the operation to 88.1 ± 11.7 at follow-up 2 years postoperatively (P = .001). The mean Knee Society function score improved significantly from 57.8 ± 9.1 before the operation to 84.3 ± 12.0 at follow-up 2 years postoperatively (P = .001). In group B (mechanical tibiofemoral angle >0° and <6°, ideal correction group), the mean Knee Society knee score improved significantly from 68.7 ± 12.0 before the operation to 93.8 ± 5.3 at follow-up 2 years postoperatively (P = .001). The mean Knee Society function score improved significantly from 62.8 ± 11.8 before the operation to 91.2 ± 8.5 at follow-up 2 years postoperatively (P = .001). In group C (mechanical tibiofemoral angle ≥6°, overcorrection group), the mean Knee Society knee score improved significantly from 72.8 ± 11.9 before the operation to 81.9 ± 7.0 at follow-up 2 years postoperatively (P = .001). The mean Knee Society function score improved significantly from 64.0 ± 6.9 before the operation to 89.0 ± 7.3 at follow-up 2 years postoperatively (P = .001). Significant differences were observed between postoperative limb alignment and the mean Knee
be cartilage regeneration after HTO and a correlation between the clinical outcome and regeneration of the articular cartilage, as well as the postoperative limb alignment, at 2 years postoperatively. Few arthroscopic studies have focused on the cartilage regeneration after HTO.\textsuperscript{5,21-28} However, 2 reports concerning second-look arthroscopic assessment after medial opening-wedge HTO have been published.\textsuperscript{29,33} Only 1 report concerning second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge HTO has been published.\textsuperscript{12} So, this study is the second report concerning the second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge HTO.

HTO is a well-established and effective procedure for the relief of pain and restoration of function in active, young and middle-aged patients with medial osteoarthritis of the knee, and this result has been reproduced by numerous other researchers as well.\textsuperscript{1-5} For avoidance of complications accompanying lateral closing-wedge HTO, medial opening-wedge HTO has regained popularity since improvements in the operative techniques have been made, and special implants for this procedure have been developed.\textsuperscript{6-20} However, no report concerning the cartilage regeneration after medial opening-wedge HTO has been published.

Few studies concerning the cartilage regeneration after lateral closing-wedge HTO for knees with medial-compartment osteoarthritis have been reported.\textsuperscript{5,21-28} Some authors have reported cartilage regeneration after lateral closing-wedge HTO. Most recently, Okahashi et al.\textsuperscript{25} suggested that improvement of the joint cartilage status was confirmed in the medial femoral condyle in 28 knees (93%) and in the medial tibial condyle in 27 knees (90%). They performed arthroscopic debridement consisting of irrigation of joint debris and removal of any major loose bodies. Moreover, they reported that regenerated cartilage was hyaline-like cartilage in 6 cases through histologic examination. Kanamiya et al.\textsuperscript{23} showed improvement to white scattering and partial or even cartilage regeneration in 55 knees (95%). Arthroscopic debridement consisted of irrigation of joint debris, removal of major loose bodies, and resection of large osteophytes around the intercondylar notch. However, abrasion arthroplasty was not performed in any case. Wakabayashi et al.\textsuperscript{24} reported cartilage regeneration in 27 knees (39%). No shaving technique was used in any of the 67 patients at

### Table 2. Clinical Outcome According to Postoperative Limb Alignment

<table>
<thead>
<tr>
<th></th>
<th>PreKSS</th>
<th>PreKSSF</th>
<th>PostKSS</th>
<th>PostKSSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A (PostTFA ≤0°)</td>
<td>64.6 ± 11.2</td>
<td>57.8 ± 9.1</td>
<td>88.1 ± 11.7</td>
<td>84.3 ± 12.0</td>
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<tr>
<td>Group B (PostTFA &gt;0° and &lt;6°)</td>
<td>68.7 ± 12.0</td>
<td>62.8 ± 11.8</td>
<td>93.8 ± 5.3</td>
<td>91.2 ± 8.5</td>
</tr>
<tr>
<td>Group C (PostTFA ≥6°)</td>
<td>72.8 ± 11.9</td>
<td>64.0 ± 6.9</td>
<td>81.9 ± 7.0</td>
<td>89.0 ± 7.3</td>
</tr>
<tr>
<td>P value</td>
<td>.229</td>
<td>.230</td>
<td>&lt;.001</td>
<td>.013</td>
</tr>
</tbody>
</table>

PostKSS, postoperative Knee Society knee score; PostKSSF, postoperative Knee Society function score; PostTFA, postoperative mechanical tibiofemoral angle; PreKSS, preoperative Knee Society knee score; PreKSSF, preoperative Knee Society function score.

Table 3. Medial Femoral Condyle Articular Cartilage Regeneration Grade According to Postoperative Limb Alignment

<table>
<thead>
<tr>
<th></th>
<th>Immature</th>
<th>Mature</th>
<th>Grade 1</th>
<th>Grade 2</th>
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<tbody>
<tr>
<td>Group A</td>
<td>15</td>
<td>1 (6%)</td>
<td>4</td>
<td>12 (75%)</td>
</tr>
<tr>
<td>Group B</td>
<td>129</td>
<td>4 (3%)</td>
<td>7</td>
<td>126 (95%)</td>
</tr>
<tr>
<td>Group C</td>
<td>9</td>
<td>1 (10%)</td>
<td>1</td>
<td>9 (90%)</td>
</tr>
</tbody>
</table>

NOTE. \( P = .462 \) for statistical analysis between immature and mature regeneration. \( P = .018 \) for statistical analysis between grade 1 and grade 2 regeneration.

### Discussion

The principal findings of this study showed that the degenerative cartilage was partially regenerated in almost all cases and fully regenerated in only some cases after medial opening-wedge HTO, and postoperative limb alignment influenced the clinical outcome and regeneration of the cartilage after medial opening-wedge HTO. This study evaluated regeneration of the articular cartilage after a medial opening-wedge HTO for knees with medial-compartment osteoarthritis and assessed the clinical outcome and regeneration of the articular cartilage according to the postoperative limb alignment at follow-up 2 years postoperatively. According to this study, we could confirm our hypothesis that there would be cartilage regeneration after HTO and a correlation between the clinical outcome and regeneration of the articular cartilage, as well as the postoperative limb alignment, at 2 years postoperatively. Few arthroscopic studies have focused on the cartilage regeneration after HTO.\textsuperscript{5,21-28} However, 2 reports concerning second-look arthroscopic assessment after medial opening-wedge HTO have been published.\textsuperscript{29,33} Only 1 report concerning second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge HTO has been published.\textsuperscript{12} So, this study is the second report concerning the second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge HTO.

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Few studies concerning the cartilage regeneration after lateral closing-wedge HTO for knees with medial-compartment osteoarthritis have been reported.\textsuperscript{5,21-28} Some authors have reported cartilage regeneration after lateral closing-wedge HTO. Most recently, Okahashi et al.\textsuperscript{25} suggested that improvement of the joint cartilage status was confirmed in the medial femoral condyle in 28 knees (93%) and in the medial tibial condyle in 27 knees (90%). They performed arthroscopic debridement consisting of irrigation of joint debris and removal of any major loose bodies. Moreover, they reported that regenerated cartilage was hyaline-like cartilage in 6 cases through histologic examination. Kanamiya et al.\textsuperscript{23} showed improvement to white scattering and partial or even cartilage regeneration in 55 knees (95%). Arthroscopic debridement consisted of irrigation of joint debris, removal of major loose bodies, and resection of large osteophytes around the intercondylar notch. However, abrasion arthroplasty was not performed in any case. Wakabayashi et al.\textsuperscript{24} reported cartilage regeneration in 27 knees (39%). No shaving technique was used in any of the 67 patients at
arthroscopy. The authors showed that regeneration of eburnated bone was better than that of fibrillated cartilage when the mechanical status was improved by correction of the leg alignment. Koshino et al.28 reported cartilage regeneration through arthrotomy in 133 knees (91%). However, drilling of a degenerative ulcer or shaving of the articular cartilage was not performed in any case in this series. Akizuki et al.22 reported cartilage regeneration in 71 knees (81%). Abrasion arthroplasty was performed to a depth of about 1 mm with a steel abrader. In our study, grade 2 regeneration was achieved in 92% of knees in the

Fig 2. Images from a 58-year-old woman show varus limb alignment before (A) medial opening-wedge HTO, (B) valgus limb alignment after medial opening-wedge HTO, and (C) well-maintained valgus limb alignment at hardware removal. (D) The articular surface shows eburnation of the articular surfaces before osteotomy. (E) The articular surface shows even coverage with fibrocartilage at 24 months postoperatively. The Knee Society knee score significantly improved from 65 points preoperatively to 95 points at the time of second-look arthroscopy. The preoperative mechanical tibiofemoral angle was $-5.4^\circ$. The postoperative mechanical tibiofemoral angle was $1.9^\circ$ at 24 months after osteotomy.

Fig 3. Images from a 60-year-old woman show varus limb alignment before (A) medial opening-wedge HTO, (B) neutral limb alignment after medial opening-wedge HTO, and (C) slightly varus limb alignment at hardware removal. (D, E) The articular surface shows eburnation of the articular surfaces before osteotomy. (F, G) The articular surface shows progression of the cartilage degeneration at 24 months postoperatively. The Knee Society knee score significantly improved from 55 points preoperatively to 80 points at the time of second-look arthroscopy. The preoperative mechanical tibiofemoral angle was $-2.3^\circ$. The postoperative mechanical tibiofemoral angle was $-0.5^\circ$ at 24 months after osteotomy.
medial femoral condyle articular cartilage and 69% of knees in the medial tibial plateau articular cartilage without any cartilage regeneration strategies.

There have been debates on the correlation between cartilage regeneration and the clinical results. Bergenudd et al. reported an improvement in the cartilage in 9 knees, no change in 8 knees, and deterioration in 2 knees at a mean of 2 years after HTO. Furthermore, they suggested that no correlation was observed between the cartilage improvement and the clinical and radiographic outcome. Akizuki et al. reported that the postoperative clinical outcome was not related to the degree of repair of the articular surface. However, Koshino et al. reported no statistically significant difference between them, although the knee score in the immature regeneration group was lower than that in the mature regeneration group. In our study no significant differences were observed at the time of second-look arthroscopy in the clinical outcome according to the grade of regeneration.

Mechanical improvement has been proved to have a significant influence on cartilage regeneration, even in the elderly knee. Mature regeneration was found more frequently in knees with increased width of the medial joint space after HTO and in knees with more than 5° of anatomic valgus angulation after osteotomy compared with those with less than 5°. Okahashi et al. also suggested that cartilage regeneration after HTO may be expected when obtained only from an adequate amount of correction at follow-up. Kanamiya et al. showed significant differences at the time of second-look arthroscopy in mean Japanese Orthopaedic Association score and mean mechanical axis percentage between medial compartments with grade 1 and grade 4 cartilage. Satisfactory clinical results after HTO were found in knees in which the mechanical axis passed within the lateral compartment (approximately 75%). Our study showed that cartilage regeneration was found more frequently in the group with ideal postoperative limb alignment (mechanical tibiofemoral angle >0° and <6°) than in the group with revarization or overcorrection. In addition, the clinical results in the group with ideal postoperative limb alignment were better than those in the group with revarization or overcorrection. Further studies are necessary to evaluate which alignment correction will produce the best clinical and regeneration results.

Limitations
This study has a number of limitations. First, this series was a retrospective, nonrandomized, sequential review. However, the number of cases was sufficient compared with previous studies. Second, all operations were performed by an experienced knee surgeon, and the results may differ in other scenarios. Third, this study reports short-term results. Long-term follow-up is needed. Fourth, the number of knees in group C (overcorrection group) was too low to allow us to make statistical statements. Fifth, female patients were predominant. However, a previous study has shown that knee osteoarthritis is more common in women than in men. Sixth, we did not perform cartilage regeneration strategies including microfracture.

Despite these limitations, this study showed that cartilage regeneration and superior short-term clinical results were found in knees with adequate valgus limb alignment through the medial opening-wedge HTO.

Conclusions
The degenerated cartilage of the medial femoral condyle and medial tibial plateau could be partially or entirely covered by newly regenerated cartilage at 2 years after adequate correction of varus deformity by medial opening-wedge HTO without cartilage regeneration strategies.

References
10. Lee SC, Jung KA, Nam CH, Jung SH, Hwang SH. The short-term follow-up results of open wedge high tibial osteotomy with using an Aescula open wedge plate and


