Patellofemoral Osteoarthritis Progresses After Medial Open-Wedge High Tibial Osteotomy: A Systematic Review

Kataoka, Kiminari ; Watanabe, Shu ; Nagai, Kanto ; Kay, Jeffrey ; Matsushita, Takehiko ; Kuroda, Ryosuke ; de Sa, Darren

(Citation)
Arthroscopy: The Journal of Arthroscopy and Related Surgery,37(10):3177-3186

(Issue Date)
2021-10

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/90008681

Patellofemoral Osteoarthritis Progresses After Medial Open Wedge High Tibial Osteotomy: A Systematic Review

ABSTRACT

Purpose: To investigate the progression of patellofemoral (PF) osteoarthritis (OA) after medial open wedge high tibial osteotomy (OWHTO), and whether PF OA progression has an influence on clinical outcomes.

Methods: According to Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA), EMBASE, PubMed and Cochrane Library were searched in June 2020 for English-language studies that presented data on PF OA or cartilage degeneration before and after OWHTO. Descriptive statistics are presented.

Results: Twenty studies comprising 1,173 patients were included. The mean age was 57.1 years (range, 18-84) with 826 (70.4%) female. The mean follow-up was 27.1 months (range, 7-144). Ten studies reported the trochlear International Cartilage Research Society (ICRS) scores, with each of these studies reporting a higher proportion of patients with grades 2-4 OA post-operatively compared to pre-operatively (relative risks=1.19 to 2.76, I^2=1.9%). Similarly, seven studies reported patellar ICRS scores and found a higher proportion with grades 2-4 OA post-operatively (relative risks=1.08 to 2.44, I^2=0%). Four studies assessed PF Kellgren-Lawrence (K-L) grade each of which reported a higher proportion of patients with grades 2-4 OA post-operatively (relative risks=1.25 to 21.0, I^2=31%). The PF OA assessments were

heterogenous, and studies using classifications except ICRS score or K-L grade were not included in statistical analysis. Fifteen studies assessed patellar height; ten studies reported significant decrease in patellar height after OWHTO. Only three studies reported clinical outcomes for patients with and without PF OA progression. Outcome reporting was variable across these studies, and relationship between PF OA progression and clinical outcome could not be definitively determined.

Conclusion: Patients appear to have progression of PF OA after medial OWHTO. However, there are currently insufficient studies with inconsistent measurements of outcomes to make meaningful conclusions for the impact of PF OA on clinical outcomes.

Level of Evidence: Level IV, systematic review of Level III-IV studies

INTRODUCTION

Conventional medial open wedge high tibial osteotomy (OWHTO), which consists of a proximal tibial tuberosity osteotomy and a transverse osteotomy, is an established surgical procedure for medial compartmental osteoarthritis (OA) of the knee.[1–4] The main purpose of an OWHTO is to realign the mechanical axis of the leg to offload the medial compartment with the aim of delaying progression to end-stage arthritis, while providing pain reduction and functional improvements.[5,6] Despite favorable outcomes following OWHTO, there are concerns related to patellofemoral (PF) joint such as patella infera and alteration in patellar tracking as an opening wedge at the transverse osteotomy moves the tibial tuberosity distal to the joint line.[7–12] Biomechanical studies have shown that conventional OWHTO is associated with a significant increase in contact pressure at PF joint,[10,13,14] which may increase the risk of PF OA progression and anterior knee pain although there could be a discrepancy between *in vitro* and *in vivo*. However, controversy still exists on whether PF OA significantly progresses after conventional OWHTO; some reported that greater amount of an opening gap or overcorrection were associated to PF OA progression[15,16] whereas other studies found that the ratio of PF OA progression after OWHTO were similar to closed-wedge HTO[8] or uni-compartmental knee arthroplasty (UKA).[17] Moreover, it remains unclear whether PF OA progression is associated with poor clinical outcomes after OWHTO; two studies[18,19] showed no significant relationship between PF OA progression and clinical outcomes while one study[20] showed PF OA progression was associated with poor outcomes. Therefore, the purpose of this

study was to investigate the progression of PF OA after conventional OWHTO, and whether PF OA progression has an influence on clinical outcomes. It was hypothesized that PF OA would progress after conventional OWHTO and would be associated with inferior clinical outcomes.

MATERIALS AND METHODS

Search strategy

Two reviewers (K.K. and S.W.) searched three databases (EMBASE, PubMed and Cochrane Library) in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) guidelines on June 23, 2020. The research question and study eligibility criteria were established *a priori* and registered in PROSPERO.

The PRISMA statement was used for reporting study selection. The inclusion criteria were as follows: 1) medial OWHTO, 2) evaluating PF OA or cartilage degeneration before and after surgery, 3) reporting clinical outcomes after the surgery. There were no restrictions on the types of study design. The exclusion criteria were as follows: 1) surgery was performed using techniques other than OWHTO, 2) the use of distal femoral osteotomy, 3) the study is written in non-English, 4) no full-text publications available, 5) review papers, conference abstracts and technical reports, 6) cadaveric studies, 7) animal studies.

The search was conducted using the terms, open* wedge AND high tibial osteotomy. Details of the screening process are outlined in Figure 1.

Study screening

Two independent reviewers screened the titles, abstracts, and full-texts of the retrieved citations.

Any discrepancy in the screening process was resolved by discussion between the two reviewers and if consensus could not be reached, a third senior reviewer was consulted. The references of the included studies were manually searched for any articles that may have eluded the initial search.

Quality assessment

Quality assessment of non-randomized cohort studies and case series was performed using the Methodological Index for Non-Randomized Studies (MINORS) quality assessment tool. This is a validated scoring tool that grades various methodological items on a scale of 0 to 2, with a maximum score of 16 for non-randomized non-comparative studies, and a maximum score of 24 for non-randomized comparative studies. [21] Two reviewers (K.K. and S.W.) independently conducted quality assessment of included studies, and any discrepancy was resolved by discussion between the two reviewers.

Data abstraction

Data were abstracted in duplicate by two reviewers and recorded in a Microsoft Excel spreadsheet. The abstracted data included the authors, year of publication, sample size, study design, level of evidence, recruitment period, country of recruitment, number of operated knees, follow-up duration, patient demographics (i.e. sample size, age, sex), and all reported pre- and post-operative clinical and functional outcomes. Kappa (κ) value was calculated for each stage of article screening to assess inter-reviewer

agreement during title, abstract, and full-text screening. Agreement was defined *a priori* as follows: $\kappa > 0.61$ to indicate substantial agreement, $0.21 \leq \kappa \leq 0.60$ as moderate agreement, and $\kappa < 0.21$ as slight agreement.[22] Descriptive statistics, such as means, ranges, and measure of variance (e.g. standard deviations, 95% confidence intervals (CI)) are presented when applicable. Intraclass correlation coefficient (ICC) was used to assess inter-reviewer agreement for MINORS quality assessment scores. In reference to a previous study, the categorization of ICC scores was determined *a priori*, whereby ICC < 0.50 indicates poor agreement, $0.50 \leq$ ICC < 0.75 indicates moderate agreement, $0.75 \leq$ ICC < 0.90 indicates good agreement, and ICC ≥ 0.90 indicates excellent agreement.[23] An *a priori* categorization of the MINORS score was set as follows: $0 <$ MINORS score < 6 to indicate very low quality of evidence, $6 \leq$ MINORS score < 10 to indicate low quality of evidence, $10 \leq$ MINORS score < 14 to indicate fair quality of evidence, and MINORS score ≥ 14 to indicate a good quality of evidence for non-randomized studies.[24]

Statistical Analysis

The primary outcome was the incidence of pre- and post-operative PF OA across studies, and secondarily this study assessed the other functional outcome measures reported across the included studies. Given the heterogeneity and methodological design of the studies included within this systematic review, the results are not pooled, and instead presented in narrative summary fashion. Descriptive statistics were

104 calculated including means, standard deviations, counts, proportions, ranges, relative risks and their
105 associated 95% confidence interval (CI). Relative risk values were calculated for each individual study by
106 comparing the proportion of patients with OA post-operatively compared to pre-operatively, with the
107 relative risk value a ratio of these proportions. As part of the narrative summary, means, proportions, and
108 relative risks are presented as a range of all values reported within the individual studies. The I^2 test was
109 used to assess heterogeneity. Values of I^2 between 25% and 49% were considered ‘‘low’’, 50%-74%
110 ‘‘moderate’’, and values greater than 75% considered to be high statistical heterogeneity.[25] Calculations
111 and forest plots were conducted using StatsDirect statistical software (Version 3.2.7, StatsDirect software,
112 Cheshire, UK).
113

RESULTS

Study Quality

The initial search strategy yielded 1023 unique studies, of which 20 studies[8,15–20,26–38] met the inclusion criteria for this review. No additional studies were identified and included through manually searching the references of the included studies (Figure 1). Substantial inter-rater agreement was achieved in title screening ($\kappa = 0.82$; 95% CI 0.78-0.86), abstract screening ($\kappa = 0.81$; 95% CI 0.76-0.86), and full text screening ($\kappa = 0.92$; 95% CI 0.84-1.00).

Among the 20 studies included in this systematic review, ten studies were level III, and ten studies were level IV. All studies were non-randomized studies. The overall MINORS score was 13.9±1.37 (max=16) in non-comparative studies (n=10), and 21.6±1.43 (max=24) in comparative studies (n=10). Two reviewers reached almost perfect agreement in MINORS score ($\kappa = 0.993$ [95% CI 0.973-0.998]).

Study Characteristics

The 20 studies consisted of 1,412 patients, and 239 patients, who underwent closed-wedge HTO, UKA, and OWHTO with the distal tibial tuberosity osteotomy (DTO), were excluded from the present review. As a result, a total of 1,173 patients were included in the present review with 826 (70.4%) female (one study did not report the sex ratio). The mean age at the surgery was 57.1 years (range, 18 to 84), and mean follow-up duration was 27.1 months (range, 7 to 144) (Table 1).

In these included studies, various classifications were used to assess the PF OA progression. International Cartilage Research Society (ICRS) grading system was most frequently used and followed by Kellgren-Lawrence (K-L) classification; seven studies used ICRS grading system, two studies used K-L classification; other two studies used both ICRS grading system and K-L classification; three studies used ICRS grading system with Merchant stage system, Iwano classification, or International Knee Documentation Committee (IKDC) radiographic assessment scale; one study used K-L classification and PF joint space; other six studies used Iwano classification, modified Iwano classification, PF joint space, Merchant stage system, Ahlback classification, modified OA grading system, or delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) score (Table 1). The rate of post-operative PF OA progression in OWHTO were summarized (Table 2).

Trochlear OA (ICRS)

A total of ten studies (794 knees)[15,16,18–20,28,33,35–37] reported the trochlear cartilage status pre- and post-operatively in OWHTO using ICRS grading system (Table 2, 3).[39] Pre-operatively, the proportion of patients with ICRS scores of 2-4 ranged from 0.21 to 1.00 (I^2=90.1%). Post-operatively, the proportion of patients with trochlear ICRS scores 2-4 ranged from 0.41 to 1.00 (I^2=86.5%). When assessing the difference between the proportion of patients with grades 2-4 OA pre- and post-operatively within each study, the relative risks within these studies ranged from 1.19 to 2.76 (I^2=1.9%) (Fig. 2).

Patellar OA (ICRS)

A total of seven studies (628 knees)[15,16,19,20,28,33,35] reported the patellar ICRS scores pre- and post-operatively in OWHTO (Table 2, 4). Pre-operatively, the proportion of patients with ICRS scores of 2-4 ranged from 0.09 to 0.45 (I^2=79.2%). Post-operatively, the proportion of patients with patellar ICRS scores 2-4 ranged from 0.16 to 0.65 (I^2=82.6%). When assessing the difference between the proportion of patients with grades 2-4 OA pre- and post-operatively within each study, the relative risks ranged from 1.08 to 2.44 (I^2= 0%) (Fig. 3).

PF OA (K-L classification)

Four studies (187 knees)[8,18,19,32] assessed PF OA both pre- and post-operatively using K-L classification.[40] The proportion of patients with K-L grades 2-4 OA pre-operatively ranged from 0 to 0.14 (I^2=75.9%) across these studies. The proportion of patients with grades 2-4 OA post-operatively ranged from 0.10 to 0.22 (I^2=0%). Within each study, the proportion of patients with grades 2-4 OA was higher post-operatively than pre- operatively with relative risks within these studies ranged from 1.25 to 21.0 (I^2=31.4%).

Association between PF OA and clinical outcome

168 Three studies (203 knees)[16,19,20] reported clinical outcomes for patients with and without
169 progression of PF OA. One study (94 knees)[20] assessed Knee Injury and Osteoarthritis Outcome Score
170 (KOOS) and Kujala score, and reported that there was clinically and statistically significant worsening in
171 postoperative Kujala score (p = 0.005), KOOS-pain (p = 0.005), KOOS-activities in daily living (p =
172 0.017), KOOS-sports and recreational function (p = 0.023), and KOOS-knee-related quality of life (p =
173 0.012) in the progression group compared with non-progression group.[41–43] The remaining two studies
174 (109 knees)[16,19] assessed Knee Society Score (KSS) for patients with and without OA progression, and
175 reported that there was no clinically and statistically significant difference in postoperative KSS between
176 with and without progression of PF OA with less than 2-year follow-up.[44]
177
178 ***Patellar height and congruency***
179 Fifteen studies (994 knees)[8,15,16,18–20,26–31,34,36,37] assessed patellar height such as Caton-Deschamp
180 (CD) index, Blackburne-Peel (BP) ratio, modified BP ratio, and Insall-Salvati (IS) ratio, and eight studies
181 (402 knees)[8,17–19,26,27,34,37] assessed patellar congruency using patella tilt and patella congruence angles.
182 Of the 15 studies, ten studies (560 knees)[8,16,18,20,29–31,34,36,37] reported significant decrease in patellar height
183 after OWHTO; four of the ten studies (202 knees)[16,31,34,36,37] used CD index, three studies (139
184 knees)[8,29,30,36] used BP ratio, two studies (154 knees)[18,20] used modified BP ratio, and one study (65
185 knees)[36]used both CD index and BP ratio. In terms of patellar congruency, only one of the eight studies

found significant alteration in patellar tilt post-operatively.[18] There was also a report that the difference in patellar tilt between before and after surgery was greater in OWHTO when compared with UKA ($p = 0.01$).[17]

DISCUSSION

The main finding of this systematic review was that conventional OWHTO patients appear to have progression of both trochlea and patella OA post-operatively. Another key finding was that there is currently a lack of studies to make meaningful deductions for the effect that PF OA can have on clinical and functional outcomes, as each study included the small number of patients and the assessments of PF OA were heterogeneous. This finding suggests that further comparative studies should be needed to determine the influence of PF OA progression on clinical outcomes.

The rate of PF OA progression after conventional OWHTO, which was assessed during second look arthroscopy with ICRS grading system, ranged from 17% to 58.5% (Table 2). In addition, the rate of OA progression in trochlea appears to be higher than the rate in patella. This large distribution in the rate of PF OA progression could be attributable to the differences in patient population, the severity of the preoperative OA, the amount of opening gap, reproducibility of the assessment. In terms of assessment of cartilage status of the PF joint, ICRS grading system was the most frequently used among the included studies; however, various other classifications were used to assess the PF OA progression; K-L grading system, Iwano classification, Merchant stage system, Ahlback classification, and dGEMRIC score (Table 1). Unified classification such as ICRS grading system would be ideal and may be recommended to discuss and compare the outcomes between the different surgeons and institutions.

One suggested mechanism in postoperative PF OA progression after conventional OWHTO is

208 the alterations in patellar height and congruency.[9,10] In the present systematic review, ten studies (560
209 knees, 56.3% of knees) showed significant decrease in patellar height after conventional OWHTO
210 compared to preoperative patellar height [8,16,18,20,29–31,34,36,37] among 15 studies (994 patients) which
211 assessed patellar height. Three studies directly compared patellar height with and without PF OA
212 progression after OWHTO; however, no significant differences were observed in patellar height in those
213 studies.[16,19,20] Furthermore, only one of the eight studies found significant alterations in patella
214 congruency.[18] Taken together, it is still uncertain whether alterations in patellar height and/or patellar
215 congruency are associated with postoperative PF OA progression.

216 Several studies[16,19,20] have investigated the factors related to postoperative PF OA progression,
217 and the greater amount of medial opening gap, overcorrection, and greater changes in hip-knee-ankle
218 angle and medial proximal tibial angle between pre- and post-operation have been shown to be associated
219 with PF OA progression. These findings suggest that PF OA appears to progress after OWHTO especially
220 in patients who need a large alignment correction or patients with a preoperative severe varus alignment.
221 The studies[16,19] showed that 9° or 10° of correction angle could be a cut-off value to predict postoperative
222 PF OA progression, which concurs with biomechanical study using cadaveric knees that showed
223 significant increase in PF contact pressure from 30° through 120° with a medial opening gap of 10mm.[14]
224 Two studies[27,34] reported that postoperative medial or lateral joint space at the PF joint was significantly
225 increased with hybrid closed-wedge HTO compared to OWHTO.

Despite almost all studies reported pre and post-operative clinical outcome, only three of 20 included studies directly compared clinical outcomes with and without postoperative PF OA progression.[16,19,20] While one study showed KOOS subscales except Symptom and Kujala scores were lower in PF OA progression group than non-progression group,[20] two other studies found no significant differences in KSS between the groups.[16,19] The latter two reports were supported by the study showing no significant correlation between PF OA progression and clinical outcomes.[18] As the previous findings were inconsistent, it is currently still controversial if PF OA progression is associated with inferior clinical outcomes; hence, further comparative studies will be needed to determine the association between PF OA progression and clinical outcome.

Recent studies suggested that OWHTO with DTO might mitigate post-operative PF OA progression and patella infera.[36,37,45–49] In DTO, the tibial tubercle is attached to the proximal tibia fragment by descending osteotomy of the tibial tubercle, therefore the position of patella and tibial tubercle could be relatively preserved. Some papers reported PF cartilage status and clinical outcome after DTO. [36,37,46]Although DTO might have advantage of mitigating the PF OA progression, DTO has more pitfalls during the procedure such as a potential risk of popliteal neurovascular injury due to a screw fixation of the tibial tuberosity and delayed bony union at the tibial tuberosity. Further studies will be needed to see if DTO is better in terms of clinical outcomes and PF OA progression compared to conventional OWHTO.

Limitations

The limitations in this systematic review primarily result from those inherent in the methodology of the included primary studies. First, only levels III and IV studies were included, and each study used various measurement method to assess PF cartilage degeneration and clinical outcomes, thus there was substantial heterogeneity of the data. In addition, there is inherent bias from the retrospective nature of these methodological designs, and therefore, we are unable to discern the causative relationship between OWHTO and the progression of patellar OA. Secondly, 17 of 20 studies were performed in Asia, which may affect generalizability. Thirdly, the grading of the cartilage degeneration by second look arthroscopy appears to be assessed non-blindly in the most studies except one study[37], which might have resulted in bias. Fourthly, exclusion of non-English studies may have resulted in selection bias. Finally, the possibility of the natural age-dependent progression of the PF OA could not be excluded as several included studies mentioned as a limitation.[16,18,26,28]

CONCLUSION

Patients appear to have progression of PF OA after medial OWHTO. However, there are currently insufficient studies with inconsistent measurements of outcomes to make meaningful conclusions for the impact of PF OA on clinical outcomes.

REFERENCES

1. Schallberger A, Jacobi M, Wahl P, Maestretti G, Jakob RP. High tibial valgus osteotomy in unicompartmental medial osteoarthritis of the knee: A retrospective follow-up study over 13-21 years. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:122-127.

2. Shim JS, Lee SH, Jung HJ, Lee H Il. High tibial open wedge osteotomy below the tibial tubercle: Clinical and radiographic results. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:57-63.

3. Floerkemeier S, Staubli AE, Schroeter S, Goldhahn S, Lobenhoffer P. Outcome after high tibial open-wedge osteotomy: A retrospective evaluation of 533 patients. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:170-180.

4. Jin C, Song EK, Santoso A, Ingale PS, Choi IS, Seon JK. Survival and Risk Factor Analysis of Medial Open Wedge High Tibial Osteotomy for Unicompartment Knee Osteoarthritis. *Arthroscopy*. 2020;36:535-543.

5. Agneskirchner JD, Hurschler C, Wrann CD, Lobenhoffer P. The effects of valgus medial opening wedge high tibial osteotomy on articular cartilage pressure of the knee: a biomechanical study. *Arthroscopy*. 2007;23:852-861.

6. Mina C, Garrett WE, Pietrobon R, Glisson R, Higgins L. High tibial osteotomy for unloading osteochondral defects in the medial compartment of the knee. *Am J Sports Med*. 2008;36:949-955.

7. Bito H, Takeuchi R, Kumagai K, et al. Opening wedge high tibial osteotomy affects both the lateral patellar tilt and patellar height. *Knee Surg Sports Traumatol Arthrosc*. 2010;18:955-960.

8. Song IH, Song EK, Seo HY, Lee KB, Yim JH, Seon JK. Patellofemoral alignment and anterior knee pain after closing- and opening-wedge valgus high tibial osteotomy. *Arthroscopy*. 2012;28:1087-1093.

9. Bin SI, Kim HJ, Ahn HS, Rim DS, Lee DH. Changes in Patellar Height After Opening Wedge and Closing Wedge High Tibial Osteotomy: A Meta-analysis. *Arthroscopy*. 2016;32:2393-2400.

10. Gaasbeek R, Welsing R, Barink M, Verdonschot N, Van Kampen A. The influence of open and closed high tibial osteotomy on dynamic patellar tracking: A biomechanical study. *Knee Surg Sports Traumatol Arthrosc*. 2007;15:978-984.

11. Portner O. High Tibial Valgus Osteotomy: Closing, Opening or Combined? Patellar Height as a Determining Factor. *Clin Orthop Relat Res*. 2014;472:3432-3440.

12. Otsuki S, Murakami T, Okamoto Y, et al. Risk of patella baja after opening-wedge high tibial osteotomy. *J Orthop Surg (Hong Kong)*. 2018;26:1-6.

13. Stoffel K, Willers C, Korshid O, Kuster M. Patellofemoral contact pressure following high tibial osteotomy: A cadaveric study. *Knee Surg Sports Traumatol Arthrosc*. 2007;15:1094-1100.

14. Javidan P, Adamson GJ, Miller JR, et al. The Effect of Medial Opening Wedge Proximal Tibial Osteotomy on Patellofemoral Contact. *Am J Sports Med*. 2013;41:80-86.

15. Yoon TH, Choi CH, Kim SJ, Kim SH, Kim NH, Jung M. Effect of Medial Open-Wedge High Tibial Osteotomy on the Patellofemoral Joint According to Postoperative Realignment. *Am J Sports Med*. 2019;47:1863-1873.

16. Tanaka T, Matsushita T, Miyaji N, et al. Deterioration of patellofemoral cartilage status after medial open-wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2019;27:1347-1354.

17. Oh KJ, Kim YC, Lee JS, Chang YS, Shetty GM, Nha KW. Open-wedge high tibial osteotomy versus unicompartmental knee arthroplasty: no difference in progression of patellofemoral joint arthritis. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:767-772.

18. Goshima K, Sawaguchi T, Shigemoto K, Iwai S, Nakanishi A, Ueoka K. Patellofemoral Osteoarthritis Progression and Alignment Changes after Open-Wedge High Tibial Osteotomy Do Not Affect Clinical Outcomes at Mid-term Follow-up. *Arthroscopy*. 2017;33:1832-1839.

19. Otakara E, Nakagawa S, Arai Y, et al. Large deformity correction in medial open-wedge high tibial osteotomy may cause degeneration of patellofemoral cartilage: A retrospective study. *Medicine (Baltimore)*. 2019;98:e14299.

20. Lee SS, So SY, Jung EY, Kim HJ, Lee BH, Wang JH. Predictive Factors for Patellofemoral Degenerative Progression After Opening-Wedge High Tibial Osteotomy. *Arthroscopy*. 2019;35:1703-1710.

21. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (Minors): Development and validation of a new instrument. *ANZ J Surg*. 2003;73:712-716.

22. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. *Biometrics*. 1977;33:159-174.

23. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med*. 2016;15:155-163.

24. Horner NS, Moroz PA, Bhullar R, et al. Open versus arthroscopic Latarjet procedures for the treatment of shoulder instability: A systematic review of comparative studies. *BMC Musculoskelet Disord*. 2018;19:255.

25. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21:1539-1558.

26. Moon HS, Choi CH, Jung M, et al. The effect of medial open wedge high tibial osteotomy on the patellofemoral joint: Comparative analysis according to the preexisting cartilage status. *BMC Musculoskelet Disord*. 2019;20:607.

27. Ishimatsu T, Takeuchi R, Ishikawa H, et al. Hybrid closed wedge high tibial osteotomy improves patellofemoral joint congruity compared with open wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2019;27:1299-1309.

28. Kim KI, Kim DK, Song SJ, Lee SH, Bae DK. Medial Open-Wedge High Tibial Osteotomy May Adversely Affect the Patellofemoral Joint. *Arthroscopy*. 2017;33:811-816.

29. Kolb W, Guhlmann H, Windisch C, Kolb K, Koller H, Grützner P. Opening-wedge high tibial osteotomy with a locked low-profile plate. *J Bone Joint Surg Am*. 2009;91:2581-2588.

30. El Amrani MH, Lévy B, Scharycki S, Asselineau A. Patellar height relevance in opening-wedge high tibial osteotomy. *Orthop Traumatol Surg Res*. 2010;96:37-43.

31. Yabuuchi K, Kondo E, Onodera J, et al. Clinical Outcomes and Complications During and After Medial Open-Wedge High Tibial Osteotomy Using a Locking Plate: A 3- to 7-Year Follow-up Study. *Orthop J Sport Med*. 2020;8:2325967120922535.

32. Cho WJ, Kim JM, Kim WK, Kim DE, Kim NK, Bin S Il. Mobile-bearing unicompartmental knee arthroplasty in old-aged patients demonstrates superior short-term clinical outcomes to open-wedge high tibial osteotomy in middle-aged patients with advanced isolated medial osteoarthritis. *Int Orthop*. 2018;42:2357-2363.

33. Lee SS, Lee H Il, Cho ST, Cho JH. Comparison of the outcomes between two different target points after open wedge high tibial osteotomy: The Fujisawa point versus the lateral tibial spine. *Knee*. 2020;27:915-922.

34. Otsuki S, Murakami T, Okamoto Y, et al. Hybrid high tibial osteotomy is superior to medial opening high tibial osteotomy for the treatment of varus knee with patellofemoral osteoarthritis.

Knee Surg Sports Traumatol Arthrosc. 2019;27:1332-1338.

35. Lee OS, Lee SH, Mok SJ, Lee YS. Comparison of the regeneration of cartilage and the clinical outcomes after the open wedge high tibial osteotomy with or without microfracture: A retrospective case control study. *BMC Musculoskelet Disord*. 2019;20:267.

36. Horikawa T, Kubota K, Hara S, Akasaki Y. Distal tuberosity osteotomy in open-wedge high tibial osteotomy does not exacerbate patellofemoral osteoarthritis on arthroscopic evaluation. *Knee Surg Sports Traumatol Arthrosc*. 2020;28:1750-1756.

37. Ogawa H, Matsumoto K, Yoshioka H, Sengoku M, Akiyama H. Distal tibial tubercle osteotomy is superior to the proximal one for progression of patellofemoral osteoarthritis in medial opening wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2020;28:3270-3278.

38. d'Entremont A, McCormack R, Agbanlog K, et al. Cartilage health in high tibial osteotomy using dGEMRIC: Relationships with joint kinematics. *Knee*. 2015;22:156-162.

39. Brittberg M, Winalski CS. Evaluation of cartilage injuries and repair. *J Bone Joint Surg Am*. 2003;85:58-69.

40. Kellgre JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16:494-502.

41. Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. *Arthroscopy*. 1993;9:159-163.

42. Crossley KM, Bennell KL, Cowan SM, Green S. Analysis of outcome measures for persons with patellofemoral pain: Which are reliable and valid? *Arch Phys Med Rehabil*. 2004;85:815-822.

43. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): From joint injury to osteoarthritis. *Health Qual Life Outcomes*. 2003;1:64.

44. Lizaur-Utrilla A, Gonzalez-Parreño S, Martinez-Mendez D, Miralles-Muñoz FA, Lopez-Prats FA. Minimal clinically important differences and substantial clinical benefits for Knee Society Scores. *Knee Surg Sports Traumatol Arthrosc*. 2020;28:1473-1478.

45. Gaasbeek RDA, Sonneveld H, Van Heerwaarden RJ, Jacobs WCH, Wymenga AB. Distal tuberosity osteotomy in open wedge high tibial osteotomy can prevent patella infera: A new technique. *Knee*. 2004;11:457-461.

46. Erquicia J, Gelber PE, Perelli S, et al. Biplane opening wedge high tibial osteotomy with a distal tuberosity osteotomy, radiological and clinical analysis with minimum follow-up of 2 years. *J Exp Orthop*. 2019;6:10.

47. Esenkaya I, Unay K. Proximal medial tibial biplanar retrotubercle open wedge osteotomy in medial knee arthrosis. *Knee*. 2012;19:416-421.

48. Keyhani S, Abbasian MR, Kazemi SM, et al. Modified retro-tubercle opening-wedge versus conventional high tibial osteotomy. *Orthopedics*. 2011;34:90-90.

49. Krause M, Drenck TC, Korthaus A, Preiss A, Frosch KH, Akoto R. Patella height is not altered

by descending medial open-wedge high tibial osteotomy (HTO) compared to ascending HTO. *Knee Surg Sports Traumatol Arthrosc*. 2018;26:1859-1866.

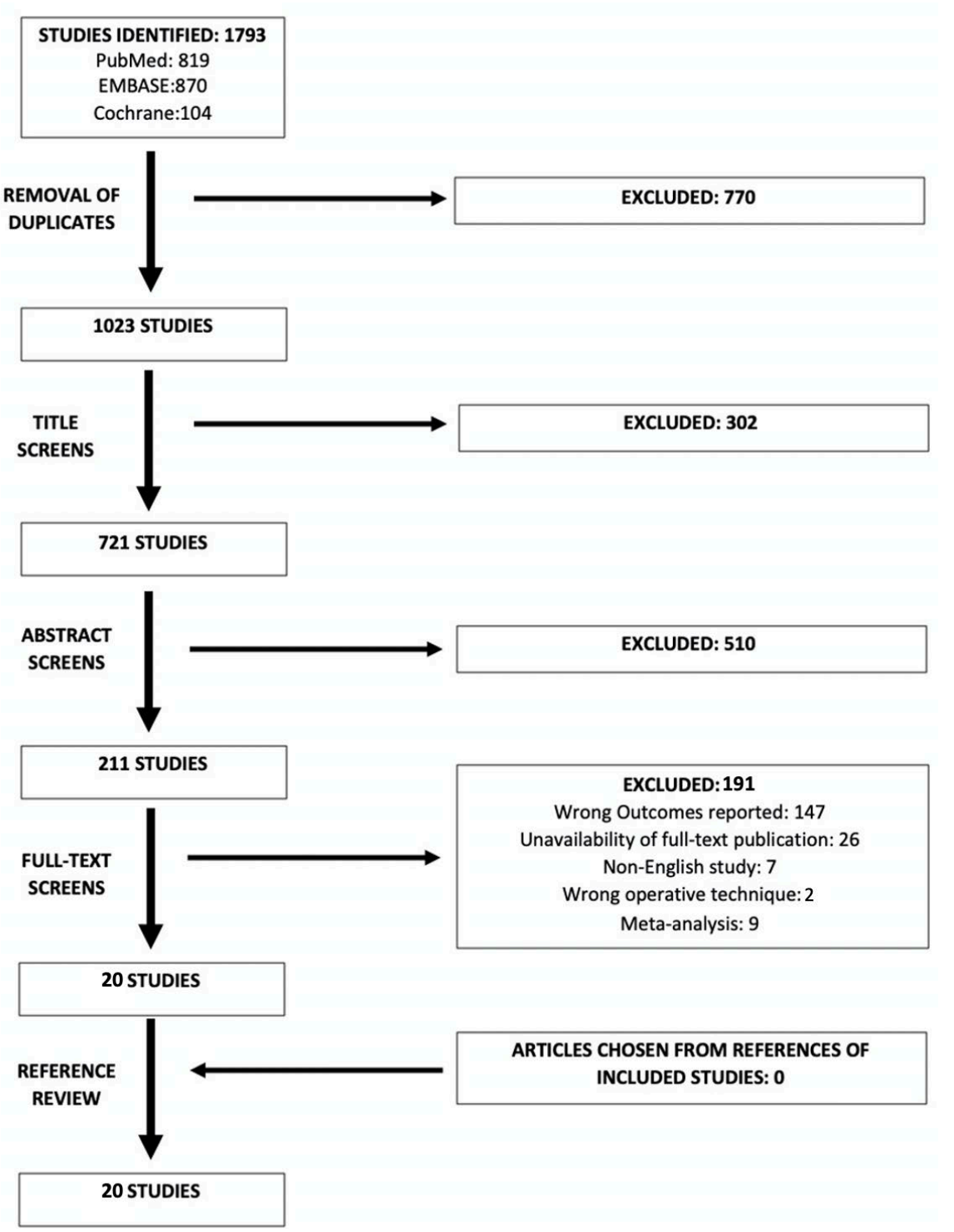
FIGURE LEGENDS AND TABLES

Fig 1. PRISMA flow diagram of the screening process for literature on PF OA progression after OWHTO

Fig 2. Relative risks of trochlea OA

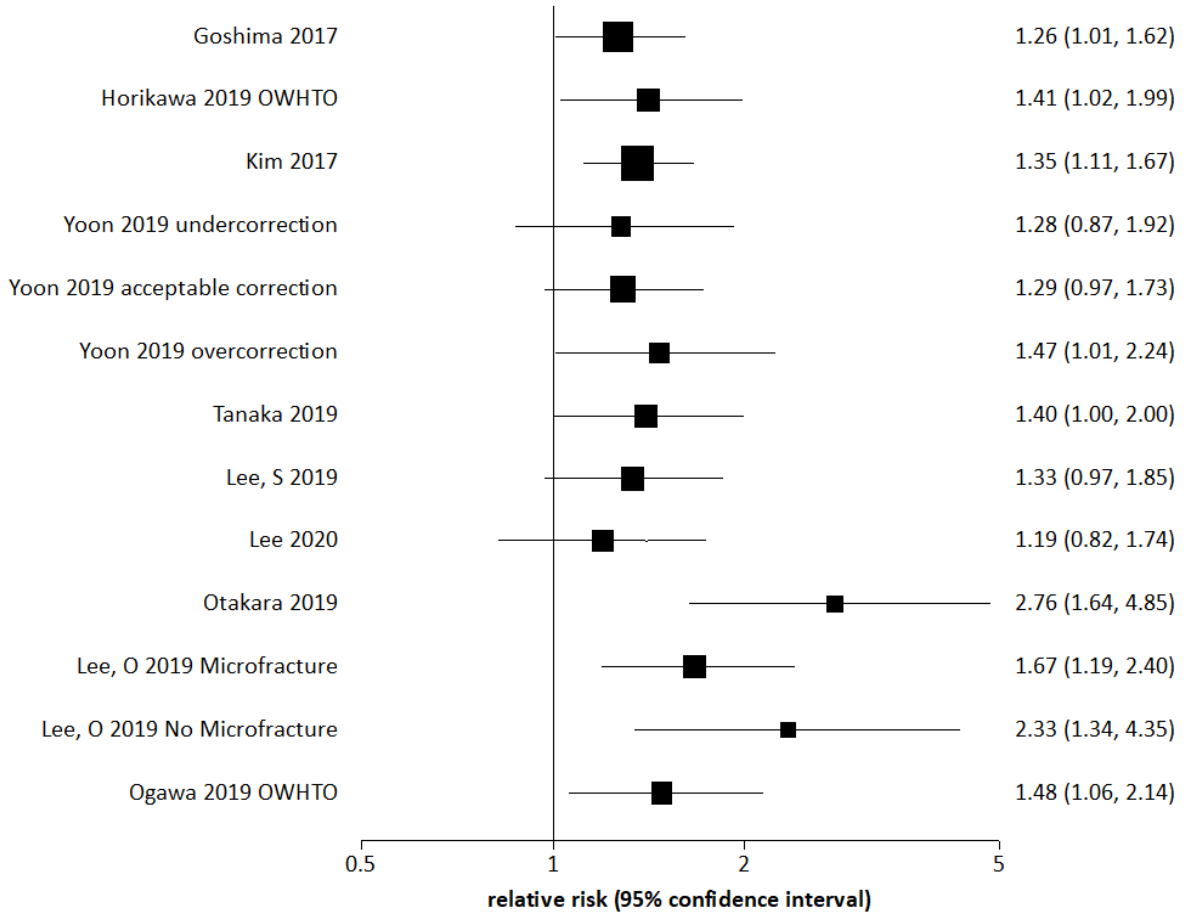
Fig 3. Relative risks of patella OA

409



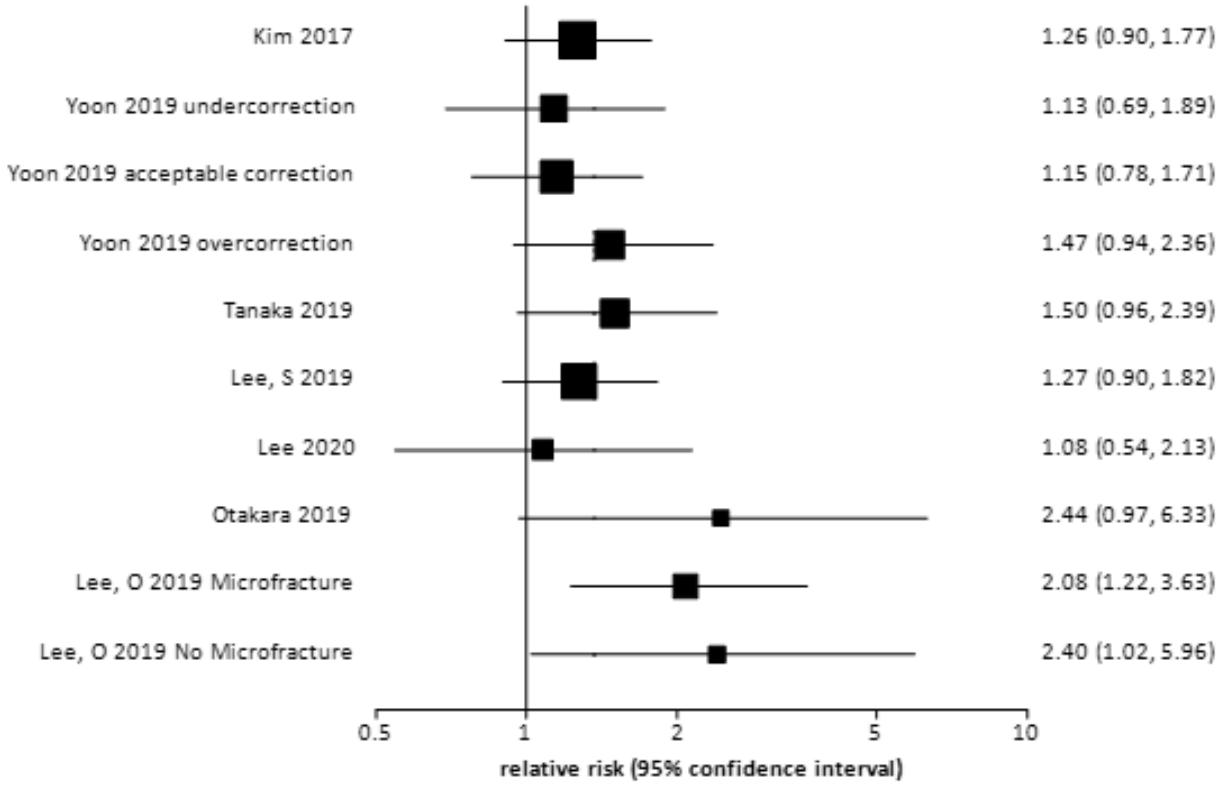
411 **Fig 1.**

412


Goshima 2017
1.26 (1.01, 1.62)
Horikawa 2019 OWHTO
1.41 (1.02, 1.99)
Kim 2017
1.35 (1.11, 1.67)
Yoon 2019 undercorrection
1.28 (0.87, 1.92)
Yoon 2019 acceptable correction
1.29 (0.97, 1.73)
Yoon 2019 overcorrection
1.47 (1.01, 2.24)
Tanaka 2019
1.40 (1.00, 2.00)
Lee, S 2019
1.33 (0.97, 1.85)
Lee 2020
1.19 (0.82, 1.74)
Otakara 2019
2.76 (1.64, 4.85)
Lee, O 2019 Microfracture
1.67 (1.19, 2.40)
Lee, O 2019 No Microfracture
2.33 (1.34, 4.35)
Ogawa 2019 OWHTO
1.48 (1.06, 2.14)
0.5
1
2
5
relative risk (95% confidence interval)

414 **Fig 2.**

415


Kim 2017
1.26 (0.90, 1.77)
Yoon 2019 undercorrection
1.13 (0.69, 1.89)
Yoon 2019 acceptable correction
1.15 (0.78, 1.71)
Yoon 2019 overcorrection
1.47 (0.94, 2.36)
Tanaka 2019
1.50 (0.96, 2.39)
Lee, S 2019
1.27 (0.90, 1.82)
Lee 2020
1.08 (0.54, 2.13)
Otakara 2019
2.44 (0.97, 6.33)
Lee, O 2019 Microfracture
2.08 (1.22, 3.63)
Lee, O 2019 No Microfracture
2.40 (1.02, 5.96)
0.5
1
2
5
10
relative risk (95% confidence interval)

417 **Fig 3.**

418

419 **Table 1.** Study demographics

420 Values are shown as mean (range). MINORS, Methodological Index for Non-Randomized Studies; PF, patellofemoral; OWHTO, open

421 wedge high tibial osteotomy; K-L, Kellgren-Lawrence; KSS, Knee Scoring System; HSS, Hospital for Special Surgery; dGEMRIC,

422 delayed gadolinium-enhanced magnetic resonance imaging of cartilage; IKS, International Knee Society; ICRS, International

423 Cartilage Repair Society; JOA, Japanese Orthopedic Association; OKS, Oxford Knee Score; KOOS, Knee injury and Osteoarthritis

424 Outcome Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis; IKDC, International Knee Documentation

425 Committee; OA, osteoarthritis

Author	Year	Country	Study design (level of evidence)	MINORS score	Surgical technique	Number of knees	%Female	Age, years	Follow-up duration, months	PF assessment	clinical outcome
Cho W et al.[32]	2018	Korea	case control (III)	19 of 24	OWHTO	20	60	58.4 (50-70)	48.4	K-L grade	KSS, HSS score
d'Entremont A et al.[38]	2015	Canada	case series (IV)	13 of 16	OWHTO	10	0	48.3	12	dGEMRIC score	
El Amrani M et al.[30]	2010	France	case series (IV)	12 of 16	OWHTO	40	36.1	55.0 (44-67)	50.4 (21.6-144)	modified Iwano classification	IKS scale
Gosima K et al.[18]	2017	Japan	case series (IV)	15 of 16	OWHTO	60	71.7	61.8 (38-84)	58.2 (25-106)	ICRS grade, K-L grade	JOA score, OKS

Horikawa T et al.[36]	2019	Japan	case control (III)	21 of 24	OWHTO	65	73.8	63.0 (49-78)	12	ICRS grade	JOA score
Ishimatsu T et al.[27]	2019	Japan	case control (III)	22 of 24	OWHTO	36	74.2	66.0 (46-79)	64.4 (60-77)	Iwano classification, PF joint space	KOOS, OKS
Kim K et al.[28]	2017	Korea	case series (IV)	13 of 16	OWHTO	114	90.4	56.34 (40-69)	26.1 (21.6-32.0)	ICRS grade, Merchant stage system	KSS
Kolb W et al.[29]	2009	Germany	case series (IV)	12 of 16	OWHTO	49		49.2 (18-66)	52.0 (30-66)	Ahlback classification	Lysholm score, HSS score
Lee O et al.[35]	2019	Korea	case control (III)	22 of 24	OWHTO	87	49.4	57	23.4	ICRS grade	KSS, WOMAC index
Lee S et al.[20]	2019	Korea	case series (IV)	14 of 16	OWHTO	94	72.3	51.7 (21-64)	21.4 (18-55)	ICRS grade	KOOS, Kujala score
Lee S et al.[33]	2020	Korea	case control (III)	21 of 24	OWHTO	89	86.5	55.6 (40-71)	19.8 (12.3-46.5)	ICRS grade	IKDC subjective score, WOMAC index
Moon H et al.[26]	2019	Korea	case control (III)	23 of 24	OWHTO	92	71.7	54.9	21.5	ICRS grade, Iwano classification	IKDC subjective score, Kujala score
Ogawa H et al.[37]	2019	Japan	case series (IV)	16 of 16	OWHTO	41	69.0	62.8 (48-75)	15.2 (12-25)	ICRS grade	KSS
Oh K et al.[17]	2016	Korea	case control (III)	23 of 24	OWHTO	42	71.4	58.6 (55-63)	65.3 (61-100)	modified OA grading system	Samsung Medical Center

											patellofemoral scoring sysytem
Otakara E et al.[19]	2019	Japan	case series (IV)	15 of 16	OWHTO	57	73.7	54.1	20.5	ICRS grade, K-L grade	KSS
Otsuki S et al.[34]	2019	Japan	case control (III)	23 of 24	OWHTO	24	45.8	66.6	31.0 (21-48)	K-L grade, PF joint space	Kujala score
Song I et al.[8]	2012	Korea	case control (III)	23 of 24	OWHTO	50	80.0	57.9 (49-65)	42.4 (36-48)	K-L grade	HSS score
Tanaka T et al.[16]	2019	Japan	case series (IV)	15 of 16	OWHTO	52	40.4	56.0	16.3	ICRS grade	KSS
Yabuuchi K et al.[31]	2020	Japan	case series (IV)	14 of 16	OWHTO	85	82.5	61.5 (40-78)	13.0 (7-30)	ICRS grade	KOOS, JOA score
Yoon T et al.[15]	2019	Korea	case control (III)	19 of 24	OWHTO	135	75.6	56.2	23.6	ICRS grade, IKDC radio-graphic assessment scale	KOOS, Shelbourne and Trumper score

Table 2. Rate of postoperative PF OA progression in ICRS grade

PF, patellofemoral; OA, osteoarthritis; ICRS, International Cartilage Repair Society; OWHTO, open wedge high tibial osteotomy; DTO, distal tubercle osteotomy; posop, postoperative; AKP, anterior knee pain; MA, mechanical axis; KOOS, Knee injury and Osteoarthritis Outcom Score; HKA, hip-knee-ankle angle; MPTA, medial proximal tibial angle; KSS, Knee Society Score.

Author	Rate of postoperative PF OA progression (ICRS)	Note
Goshima et al.	27/60 knees (45%) in PF joint	No significant correlation with clinical outcome
Horikawa et al.	21/65 knees (32.3%) in PF joint	Significant higher progression in OWHTO than DTO
Kim et al.	25/114 knees (21.9%) in patella, 47/114 knees (41.2%) in trochlea	11.4% had postop AKP and was related to ICRS grade at 2nd look
Lee O et al.	39/87 knees (44.8%) in patella, 35/87 knees (51.7%) in trochlea	No significant difference in progression with or without microfracture
Lee S et al. 2019	28/94 knees (30%) in PF joint [16/94 knees (17%) in patella, 26/94 knees (28%) in trochlea]	Postop MA (overcorrection) was the most related to PF OA progression Kujala and KOOS were lower in progression group
Lee S et al. 2020	16/89 knees (18.0%) in PF joint	PF OA progression in OWHTO aiming at Fujisawa point was higher than that aiming at lateral tibial spine (overcorrection led to PF OA progression)
Ogawa et al.	24/41 knees (58.5%) in medial facet of patella, 24/41 knees (58.5%) in lateral facet of patella, 23/41 knees (56.1%) in trochlea	OWHTO has higher PF OA progression than DTO DTO has better clinical outcome
Otakara et al.	30/57 knees (52.6%) in PF joint	Change in HKAA and MPTA were greater in PF OA progression group No difference in postop KSS
Tanaka et al.	17/52 knees (32.7%) in PF joint, 12/52 knees (23.0%) in patella, 16/52 knees (30.8%) in trochlea	Change in MPTA, medial opening gap was greater in progression group
Yoon et al.	53/135 knees (39.3%) in trochlea, 32/135 knees (23.7%) in patella	PF OA progression is higher in overcorrection group and overcorrection was related to worse clinical outcome

433 **Table 3.** Changes in ICRS grade of Trochlea

434 ICRS, International Cartilage Repair Society; HTO, high tibial osteotomy.

Author	Year		Number of knees	Period between HTO and 2nd look arthroscopy (months)	ICRS grade (preoperative / postoperative)				
					0	1	2	3	4
Goshima et al.	2017		60	19	6 / 5	16 / 7	24 / 24	14 / 24	0 / 0
Horikawa et al.	2019		65	12	0 / 0	36 / 24	19 / 20	9 / 18	1 / 3
Kim et al.	2017		114	26.1	7 / 3	45 / 27	25 / 32	17 / 32	20 / 20
Lee O et al.	2019	microfracture	57	24	7 / 2	26 / 15	18 / 29	5 / 9	1 / 2
		no microfracture	30	24	9 / 2	12 / 7	6 / 16	3 / 5	0 / 0
Lee S et al.	2019		94	21.4	36 / 23	22 / 23	27 / 24	9 / 17	0 / 7
Lee S et al.	2020		89	19.8	29 / 26	29 / 26	13 / 15	16 / 19	2 / 3
Ogawa et al.	2019		41	15.2	9 / 2	11 / 8	16 / 7	5 / 21	0 / 3
Otakara et al.	2019		57	20.5	16 / 7	29 / 16	9 / 23	3 / 9	0 / 0
Tanaka et al.	2019		52	16.3	12 / 5	15 / 12	8 / 13	12 / 18	5 / 4
Yoon et al.	2019	undercorrection	33	23.3	3 / 2	12 / 8	9 / 11	6 / 8	3 / 4
		acceptable correction	68	23.6	8 / 4	25 / 19	15 / 20	12 / 14	8 / 11
		overcorrection	34	23.9	2 / 0	15 / 9	7 / 8	7 / 10	3 / 7

435

436 **Table 4.** Changes in ICRS grade of Patella

437 ICRS, International Cartilage Repair Society; HTO, high tibial osteotomy.

Author	Year		Number of knees	Period between HTO and 2nd look arthroscopy (months)	ICRS grade (preoperative/postoperative)				
					0	1	2	3	4
Kim et al.	2017		114	26.1	9 / 6	67 / 60	25 / 28	7 / 11	6 / 9
Lee O et al.	2019	microfracture	57	24	15 / 1	29 / 29	9 / 22	2 / 4	2 / 1
		no microfracture	30	24	9 / 4	16 / 14	4 / 11	1 / 1	0 / 0
Lee S et al.	2019		94	21.4	36 / 29	25 / 23	26 / 26	7 / 14	0 / 2
Lee S et al.	2020		89	19.8	35 / 32	41 / 43	9 / 10	3 / 2	1 / 2
Otakara et al.	2019		57	20.5	16 / 9	36 / 35	5 / 10	0 / 2	0 / 0
Tanaka et al.	2019		52	16.3	14 / 8	20 / 17	12 / 18	6 / 7	0 / 2
Yoon et al.	2019	undercorrection	33	23.3	3 / 3	15 / 13	10 / 10	4 / 5	1 / 2
		acceptable correction	68	23.6	6 / 4	35 / 33	17 / 17	7 / 9	3 / 5
		overcorrection	34	23.9	4 / 2	15 / 10	9 / 12	4 / 6	2 / 4

438