



# Retaining the medial collateral ligament in high tibial medial open-wedge osteotomy mostly results in post-operative intra-articular gap reduction

Abolfazl Bagherifard<sup>1</sup> · Mahmoud Jabalameli<sup>1</sup> · Alireza Mirzaei<sup>1</sup> · Akbar Khodabandeh<sup>1</sup> · Majid Abedi<sup>1</sup> · Hooman Yahyazadeh<sup>1</sup>

Received: 17 December 2018 / Accepted: 4 March 2019 / Published online: 10 April 2019  
© European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) 2019

## Abstract

**Purpose** The current study aimed to evaluate how open-wedge high tibial osteotomy (OWHTO) without the release of medial collateral ligament (MCL) changes in vivo intra-articular joint space after the surgery.

**Methods** Patients with varus malalignment of the knee with an indication for OWHTO were included in this study. The intra-articular gap was measured before and 30 min after OWHTO without MCL release using a series of calibrated nerve hooks. The association of post-operative gap size with varus angle, medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA) and joint line convergence angle (JLCA) was also assessed.

**Results** A total of 42 knees from 38 patients were evaluated. The mean size of the intra-articular gap of the medial compartment was  $5.2 \pm 1$  mm before the osteotomy and  $3.1 \pm 2.2$  mm at 30 min post-osteotomy. The size of the intra-articular gap decreased post-operatively in 30 knees (71.5%), increased in eight knees (19%) and remained the same in the remaining four knees (9.5%). Smaller MPTA and more correction were associated with a decrease in gap size after the osteotomy ( $p = 0.01$  and  $p = 0.03$ , respectively). A significant negative correlation was observed between the correction size and the gap size after osteotomy ( $r = -0.317$ ,  $p = 0.04$ ).

**Conclusion** Intra-articular pressure of the medial compartment increases in the majority of cases following OWHTO without MCL release. Until the factors affecting this increased pressure are thoroughly identified, MCL release seems to be a wiser option during OWHTO.

**Level of evidence** III.

**Keywords** Open-wedge high tibial osteotomy · Medial collateral ligament · Gap size · Intra-articular pressure

## Abbreviations

MCL	Medial collateral ligament
OWHTO	Open-wedge high tibial osteotomy
MPTA	Medial proximal tibial angle
LDFA	Lateral distal femoral angle
JLCA	Joint line convergence angle

## Introduction

Open-wedge high tibial osteotomy (OWHTO) is a successful mode of surgery for the management of varus malalignment, as it provides good-to-excellent mid-to-long-term results [7, 10, 20, 22]. Alteration of the mechanical axis from the medial tibiofemoral compartment to the neutral or slightly lateral compartment is the ultimate goal of this surgery [2, 3].

Medial collateral ligament (MCL) is the primary restraint against knee valgus and consists of two components: superficial MCL and deep MCL [16]. There is a lack of consensus regarding the management of MCL while exposing the proximal tibia during OWHTO. While some surgeons prefer to elevate the superficial bundle of MCL sub-periosteally so that the majority of MCL bundle remains intact [10, 14], others release the MCL partially or completely from its

✉ Hooman Yahyazadeh  
yahyazadeh.h@iums.ac.ir

<sup>1</sup> Bone and Joint Reconstruction Research Center, Shafa Orthopedic Hospital, Iran University of Medical Sciences, Baharestan Square, Tehran, IR, Iran

distal origin or even transect it transversely [6, 14]. The former group believes that the released MCL can cause medial laxity of the knee joint leading to later valgus instability [9, 12, 14]. However, studies on cadaveric human knee specimens have revealed that 10° OWHTO increases the MCL tension up to 200 N [21]. When the MCL is not released, the increased contact pressure on the medial compartment will result in an ineffective osteotomy, despite the mechanical axis transfer to the lateral compartment [21]. Thus, further well-evidenced research is needed to provide a clear-cut answer about retaining or releasing the MCL in OWHTO.

The purpose of this study was to provide a consensus on this issue. To the best knowledge of the authors, no in vivo study has been performed to evaluate the intra-articular pressure of the medial compartment following OWHTO without MCL release. We hypothesized that the evaluation of the pre- and post-osteotomy intra-articular gap of the medial compartment could be used for indirect estimation of pressure on the medial compartment, as a decrease in this gap could be attributed to the increased articular pressure and vice versa. This approach was used to investigate how OWHTO without MCL release affects the intra-articular gap of the medial compartment. The null hypothesis is that retaining MCL in OWHTO has no effect on the intra-articular medial joint space after the osteotomy. If the null hypothesis is rejected, then MCL release is necessary for attaining the maximum efficacy in OWHTO.

## Materials and methods

In a prospective design, idiopathic varus patients with medial knee joint pain or initial stages of medial compartment osteoarthritis and patients with idiopathic double varus participated. Pure tibial varus deformity was confirmed by radiographs of long-leg standing alignment view. MRI was performed to rule out other ligament injuries.

Patients with a ligament injury, a history of previous knee injury or surgery, a concurrent deformity at other sites on the lower limb and those with a ligament laxity score of

more than 3 points according to the Beighton criteria [4] were excluded from the study. Patients with severe knee osteoarthritis, tricompartmental osteoarthritis or patellofemoral joint osteoarthritis were excluded from the study as well. Radiographic indices of the lower limb axial alignment including the varus angle, medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), and joint line convergence angle (JLCA) were evaluated on long-leg standing radiography (alignment view).

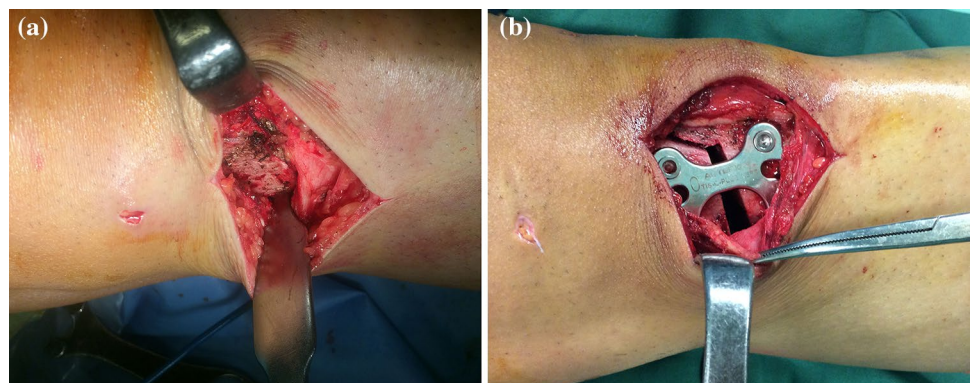
## Surgical approach

All surgeries were performed by one senior knee surgeon using the same method under the spinal anaesthesia. The gap test was done in the mid-portion of the medial meniscus with the knee positioned at 30° of flexion using a sterile bevel as described by Noyes et al. [13]. For this purpose, a series of standard calibrated nerve hooks were used to measure the joint gap between the femoral condyle and the tibia at the innermost edge of the medial meniscus. After skin incision, about 3 cm of MCL was elevated sub-periosteally and retracted posteriorly. Distal insertion, in addition to other parts of the MCL, and the pes anserinus insertion sites were left intact (Fig. 1a). The correction destination was planned at a Mikulicz point of 50%. An osteotomy was carried out as preoperatively planned while maintaining the anterior gap of the osteotomy site at approximately one-half of the posterior gap to maintain the tibial slope. The osteotomy site was secured with a Puddu plate (Arthrex®) (Fig. 1b). The elevated part of the MCL was then sutured to its previous site. At 30 min after the osteotomy, the arthroscopy and the gap test were repeated using the same method.

In 20 arthroscopies, the gap size was measured twice by the same surgeon (for the evaluation of the intra-rater reliability) and once with a second surgeon (for the evaluation of inter-rater reliability). The interval between the two measurements was 30 min.

This study was approved by the Institutional Review Board of Iran University of Medical Sciences (code

**Fig. 1** **a** Intra-operative view of open-wedge high tibial osteotomy showing the sub-periosteal elevation of MCL without distal insertion release; **b** intra-operative view of post-fixation open-wedge high tibial osteotomy without MCL release



IR.IUMS.FMD.REC.1397.243) and informed consent forms were signed by all patients before their participation in the study.

## Statistical evaluation

The sample size was calculated using the standard deviation (SD) of  $1.2^\circ$  for the medial joint opening, obtained from the study of Seo et al. [18]. With an effect size of  $2.6^\circ$ , a power of 95% and a significance level of 5%, a sample size of five patients was regarded to be sufficient to detect a clinically important difference using the two-tailed *t* test of the difference between means.

SPSS for windows version 16 was used for statistical analysis of the data. Cohen's kappa statistic was used for statistical analysis of the intra- and inter-rater reliability of the gap test. The descriptive statistics were provided as mean  $\pm$  SD or the number and percentage. The normality of the variables was tested using the Kolmogorov–Smirnov test. The paired *t* test was used for comparison of the pre- and post-operative gap size. One-way ANOVA was used to compare the means of more than two independent groups. The Chi-square test was used to assess the association between categorical variables. The Pearson's or Spearman's correlation coefficient test was used to assess potential correlations between the variables. The median split approach was used for the categorization of the variables. A *p* value  $< 0.05$  was considered significant.

## Results

A total of 42 knees from 38 patients who underwent OWHTO were examined in this study. The mean age of the patients was  $34.8 \pm 10.9$  years (range 18–51 years). The non-synthetic allograft was used as the filling agent in all surgeries. The clinical, demographic and radiographic characteristics of the patients are summarized in Table 1.

Kappa values of 0.96 and 0.92 were obtained for intra- and inter-rater reliability of the gap tests, respectively. Before osteotomy, the mean size of the intra-articular gap of the medial compartment was  $5.2 \pm 1$  mm (range 3–7 mm). The mean size of the intra-articular gap of the medial component at 30 min post-osteotomy was  $3.1 \pm 2.2$  mm with a range of 1–8 mm. This decrease was statistically significant ( $p < 0.001$ ). Accordingly, the size of the intra-articular gap decreased in 30 knees (71.5%; Fig. 2a, b), increased in eight knees (19%; Fig. 2c, d) and remained unchanged in the remaining four knees (9.5%).

A significant positive association was found between the MPTA and gap status, such that the MPTA was larger in those knees showing an increase in gap size following

**Table 1** The demographic, clinical and radiographic characteristics of the patients who underwent high tibial open-wedge osteotomy for the correction of varus malalignment

Variable	Patient number: 38 Knee number: 42
Age (year)	$34.8 \pm 10.9$
Gender	
Male	19 (50)
Female	19 (50)
Involved knee	
Right	19 (50)
Left	15 (39.5)
Both	4 (10.5)
BMI (kg/m <sup>2</sup> )	$24.2 \pm 2.23$
Varus angle (°)	$12.6 \pm 3.1$
LDFA (°)	$88.6 \pm 1.7$
MTPA (°)	$79 \pm 2.3$
JLCA (°)	$2.4 \pm 2.4$
Correction size (°)	$11 \pm 2$

The data are presented as mean  $\pm$  SD

LDFA lateral distal femoral angle, MTPA medial proximal tibial angle, JLCA joint line convergence angle

osteotomy and vice versa ( $81.1^\circ$  vs.  $78.4^\circ$ ;  $p = 0.01$ ). The correction size was significantly less in knees with an increased gap size ( $9.5^\circ$  vs.  $11.2^\circ$ ;  $p = 0.03$ ).

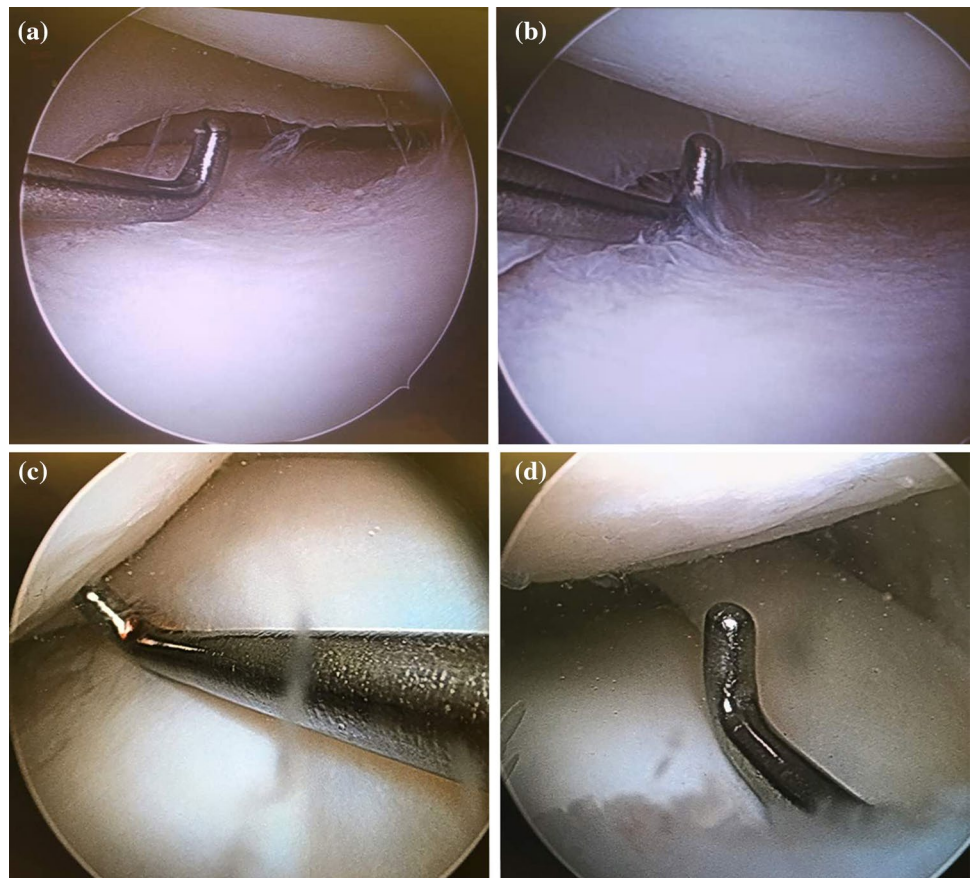
The median MPTA was  $79.5^\circ$ . When this median was used to split the MPTA data, all knees with increased gaps showed an MPTA value of  $\geq 79.5^\circ$  ( $p = 0.02$ ). The median correction size was  $11^\circ$ . After splitting the correction size data according to this median value, all knees with increased gap sizes demonstrated a correction size of  $\leq 11^\circ$  ( $p = 0.03$ ). No other significant association was observed between the gap status and the demographic or radiographic characteristics of the knees (Table 2).

A significant positive correlation was observed between the MPTA and gap change post-osteotomy ( $r = 0.479$ ;  $p = 0.002$ ). Moreover, a significant negative correlation was observed between the correction size and gap change post-osteotomy ( $r = -0.317$ ;  $p = 0.04$ ). No other significant correlation was found between the gap change and other variables.

## Discussion

The most important findings of this study were as follows: the intra-articular gap of the medial component decreased in the majority of cases (71.5%) following OWHTO without MCL release and MCL tension could be regarded as the main underlying factor. In some cases, this gap did not change after osteotomy (9.5%) and, in other cases (19%), the gap size increased. The current study revealed significant

**Fig. 2** **a** Pre-osteotomy and **b** post-osteotomy gap test in a patient with decreased medial gap following the open-wedge high tibial osteotomy without MCL release; **c** pre-osteotomy and **d** post-osteotomy gap test in a patient with increased medial gap following the open-wedge high tibial osteotomy without MCL release



**Table 2** Statistical evaluation of the association between the gap status and demographic and radiographic characteristics of the knees

Variable	Gap status			p value
	Decreased (n=30)	Not changed (n=4)	Increased (n=8)	
Age (year)	34.9 ± 10.5	40.3 ± 10.1	31.6 ± 12.9	n.s.
BMI (kg/m <sup>2</sup> )	24 ± 2.5	24.9 ± 1.5	24.7 ± 1.5	n.s.
Varus angle (°)	12.9 ± 3.1	14.7 ± 3.2	10.6 ± 2.1	n.s.
LFDA (°)	88.4 ± 1.7	89.7 ± 1.3	88.8 ± 1.7	n.s.
MTPA (°)	78.4 ± 2.3	78 ± 1.4	81.1 ± 1.6	0.011
JLCA (°)	2.6 ± 2.7	1.5 ± 1.3	2.1 ± 1.3	n.s.
Correction size (°)	11.2 ± 1.7	11 ± 2.7	9.5 ± 2	0.03

The data are presented as mean ± SD

n.s. non-significant, LFDA lateral distal femoral angle, MTPA medial proximal tibial angle, JLCA joint line convergence angle

associations between the MPTA, correction size and gap change. A larger MPTA and lower correction size were associated with less gap decrease (less pressure) post-osteotomy. In other words, increasing the correction increased strain on the MCL, which in turn increased the intra-articular pressure, which manifested as a narrower gap.

Enhanced surgical knowledge about the anatomical structures that are at risk during the different steps of osteotomy can help to optimize the surgical outcome and avoid potential complications [11, 23]. Egmond et al. [21] studied

intra-articular pressure following OWHTO with and without MCL release in seven fresh-frozen, human cadaveric knees. Despite a considerable relaxation of the MCL over time, cartilage pressure did not shift to the lateral condyle if the MCL was not released. By contrast, after the release of the superficial MCL, the cartilage pressure shifted from the medial to the lateral compartment. Although MCL release significantly increased valgus laxity, they concluded that a release of the superficial MCL is necessary for successful OWHTO, as time zero valgus laxity does not imply chronic



knee ligament instability. In general, if the release is properly performed, the patients do not complain about medial instability following OWHTO.

Agneskirchner et al. [1] evaluated the effect of OWHTO without MCL release on tibiofemoral cartilage pressure in six cadaveric human knee specimens. They reported that OWHTO without MCL release significantly increased pressure medially, while after complete release of the MCL, a significant decrease in pressure was observed. They also concluded that for effective decompression of the medial component, complete release of the MCL is necessary after OWHTO.

Seo et al. [18] evaluated the medial joint opening after OWHTO in 48 patients using serial valgus stress radiographs (at 3, 6, and 12 months after surgery). They reported that the medial joint space opening increased significantly after the release of the superficial MCL when compared with before the release. Their study also revealed that medial laxity induced by the release of the superficial MCL can be recovered by opening the osteotomy site. No problematic valgus instability of the knee joint was observed in their patients after OWHTO. Although this study revealed significant medial joint space opening after the release of the superficial MCL, it should be noted that the time zero joint line opening is pathologic, as chronic varus deformity results in contracture of the medial structures [5].

Seitz et al. [17] aimed to quantify the effect of clinically relevant OWHTO on MCL strain and the resultant tibiofemoral contact mechanics in six human cadaveric knee joints. The MCL strain was determined using strain gauges. Tibiofemoral contact mechanics were investigated using pressure-sensitive sensors. A significant increase in strain of up to 8.3% was seen in the MCL fibres associated with osteotomy. The desired lateralization of the mechanical axis was achieved only after MCL release. They concluded that the release of the MCL is mandatory in medial OWHTO.

To the best knowledge of the authors, the current *in vivo* study is the first to evaluate the intra-articular gap size as an indirect approach to measuring the intra-articular pressure after OWHTO. As the majority of earlier investigations ascertain the necessity of superficial MCL release following OWHTO, the results of this study also reveal that most will benefit from MCL release and it is suggested as essential in OWHTO, even in the presence of the increased risk of valgus instability. The results also revealed that in a subset of patients, it may not be necessary to release the MCL, as the intra-articular gap did not decrease after OWHTO without MCL release. In this respect, a significant association was found between the MPTA and the gap change after the osteotomy. MPTA is commonly used to determine the correction size and a larger MPTA leads to a smaller correction size and vice versa [15]. As a smaller correction size is equivalent to less MCL tension, little or no decrease in

the intra-articular gap could be expected in the knees with a larger MPTA and lower correction size. This hypothesis is in agreement with the results of the current study, as all patients who showed no change or increased gap size after osteotomy recorded an MPTA  $> 79.5^\circ$  and a correction size of  $< 11^\circ$ . The importance of MPTA in the recurrence of varus deformity after OWHTO has been discussed by Pornrattanameeewong et al. [15]. Factors such as the age, gender and immobilization have also been associated with the biomechanical properties of ligaments and could be determinative in the outcome of OWHTO without MCL release [8, 19]. These observations underline the need for further codification of factors that might affect the intra-articular gap after OWHTO without MCL release. In this case, MCL management in OWHTO could be more personalized and the decision to release MCL could be based upon patient characteristics, such as the MPTA.

The current study had some limitations. Egmond et al. reported that the MCL tension dropped by 10.7% at 5 min and by 24.2% at 24 h after OWHTO without MCL release. This has been explained as MCL relaxation over time. Ethically, it was not possible to re-measure the gap some hours after the end of surgery, when the MCL is probably more relaxed. This could be considered a major limitation of this study. Moreover, the accuracy of the gap test was not confirmed by intra-operative radiograph due to the unavailability of such facilities. This could be regarded as the other weakness of this study. Finally, the small number of cases did not allow multivariate analysis of the data. As discussed, intra-articular gap size following OWHTO could be affected by many factors. Identification of these factors requires future investigation with a sufficient sample size to allow multivariate analysis of the variables. Despite these limitations, the results of the present study show that in the majority of cases retaining MCL results in inefficient OWHTO imposed by the intact MCL pressure on the medial compartment. Thus, MCL release is suggested to achieve an efficacious OWHTO.

## Conclusion

The intra-articular gap of the medial component decreases in the majority of cases following OWHTO without MCL release which could be attributed to MCL tension. Because this tension prevents a pressure shift from the medial to the lateral condyle, MCL release appears to be necessary for these patients. Yet, in a subset of patients, the intra-articular gap did not decrease following OWHTO without MCL release. Further identification of factors affecting the intra-articular gap size can allow personalization of MCL management after OWHTO in future workouts. Until then,

MCL release after OWHTO is a more reasonable approach, even in exchange for the increased risk of valgus instability.

**Author contributions** AB made substantial contributions to conception and design of the study. MJ supervised the study and did the surgeries and gap tests. AM analysed the data and prepared the first draft of the article. AKH was responsible for radiographic data collection and patient recruitment. MA assisted in the surgeries and critically revised the article for important intellectual content. HY was involved in drafting the manuscript and assisted in the surgeries. All authors read and approved the final draft of the manuscript.

**Funding** This work was supported by Iran University of Medical Sciences (Grant no. IR.IUMS.FMD.REC.1397.243).

### Compliance with ethical standards

**Conflict of interest** All authors declare that they have no conflict of interest.

**Ethical approval** This research was conducted in accordance with the 1964 Helsinki Declaration.

**Informed consent** Informed consent was obtained from the patients before their participation in the study.

### References

1. Agneskirchner JD, Hurschler C, Wrann CD, Lobenhoffer P (2007) The effects of valgus medial opening wedge high tibial osteotomy on articular cartilage pressure of the knee: a biomechanical study. *Arthroscopy* 23:852–861
2. Amendola A, Bonasia DE (2010) Results of high tibial osteotomy: review of the literature. *Int Orthop* 34:155–160
3. Bagherifard A, Jabalameli M, Rezazadeh J, Askari A, Yoosefzadeh A, Mohammadpour M et al (2018) The effect of opening-wedge high tibial osteotomy on the posterior tibial slope assessed by three different evaluation methods. *Shafa Orthop J* 5:e68424
4. Beighton P, Solomon L, Soskolne C (1973) Articular mobility in an African population. *Ann Rheum Dis* 32:413
5. Bellemans J, Vandenneucker H, Vanlauwe J, Victor J (2010) The influence of coronal plane deformity on mediolateral ligament status: an observational study in varus knees. *Knee Surg Sports Traumatol Arthrosc* 18:152–156
6. Egmond-NV, Hannink G, Janssen D, Vrancken AC, Verdonshot N, Kampen AV (2017) Relaxation of the MCL after an open-wedge high tibial osteotomy results in decreasing contact pressures of the knee over time. *Knee Surg Sports Traumatol Arthrosc* 25:800–807
7. Gaasbeek RD, Nicolaas L, Rijnberg WJ, van Loon CJ, van Kampen A (2010) Correction accuracy and collateral laxity in open versus closed wedge high tibial osteotomy. A one-year randomised controlled study. *Int Orthop* 34:201–207
8. Kohn L, Sauerschnig M, Iskansar S, Lorenz S, Meidinger G, Imhoff A et al (2013) Age does not influence the clinical outcome after high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc* 21:146–151
9. Laprade RF, Bernhardson AS, Griffith CJ, Macalena JA, Wijdicks CA (2010) Correlation of valgus stress radiographs with medial knee ligament injuries: an in vitro biomechanical study. *Am J Sports Med* 38:330–338
10. Lobenhoffer P, Agneskirchner JD (2003) Improvements in surgical technique of valgus high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc* 11:132–138
11. Madry H, Goebel L, Hoffmann A, Dück K, Gerich T, Seil R et al (2017) Surgical anatomy of medial open-wedge high tibial osteotomy: crucial steps and pitfalls. *Knee Surg Sports Traumatol Arthrosc* 25:3661–3669
12. Matsumoto H, Suda Y, Otani T, Niki Y, Seedhom BB, Fujikawa K (2001) Roles of the anterior cruciate ligament and the medial collateral ligament in preventing valgus instability. *J Orthop Sci* 6:28–32
13. Noyes FR, Barber-Westin SD, Hewett TE (2000) High tibial osteotomy and ligament reconstruction for varus angulated anterior cruciate ligament-deficient knees. *Am J Sports Med* 28:282–296
14. Pape D, Duchow J, Rupp S, Seil R, Kohn D (2006) Partial release of the superficial medial collateral ligament for open-wedge high tibial osteotomy. A human cadaver study evaluating medial joint opening by stress radiography. *Knee Surg Sports Traumatol Arthrosc* 14:141–148
15. Pornrattanamanee Wong C, Narkbunnam R, Chareancholvanich K (2012) Medial proximal tibial angle after medial opening wedge HTO: a retrospective diagnostic test study. *Indian J Orthop* 46:525
16. Robinson JR, Bull AM, Thomas RR, Amis AA (2006) The role of the medial collateral ligament and posteromedial capsule in controlling knee laxity. *Am J Sports Med* 34:1815–1823
17. Seitz AM, Nelitz M, Ignatius A, Dürselen L (2018) Release of the medial collateral ligament is mandatory in medial open-wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. <https://doi.org/10.1007/s00167-018-5167-0>
18. Seo S-S, Kim C-W, Seo J-H, Kim D-H, Lee C-R (2016) Does superficial medial collateral ligament release in open-wedge high tibial osteotomy for varus osteoarthritic knees increase valgus laxity? *Am J Sports Med* 44:908–915
19. Smith AD (1994) Orthopaedic sports medicine: principles and practice. *JAMA* 272:1301–1302
20. Suero EM, Sabbagh Y, Westphal R, Hawi N, Citak M, Wahl FM et al (2015) Effect of medial opening wedge high tibial osteotomy on intraarticular knee and ankle contact pressures. *J Orthop Res* 33:598–604
21. van Egmond N, Hannink G, Janssen D, Vrancken AC, Verdonshot N, van Kampen A (2017) Relaxation of the MCL after an open-wedge high tibial osteotomy results in decreasing contact pressures of the knee over time. *Knee Surg Sports Traumatol Arthrosc* 25:800–807
22. van Egmond N, van Grinsven S, van Loon CJ, Gaasbeek RD, van Kampen A (2016) Better clinical results after closed- compared to open-wedge high tibial osteotomy in patients with medial knee osteoarthritis and varus leg alignment. *Knee Surg Sports Traumatol Arthrosc* 24:34–41
23. Yan J, Musahl V, Kay J, Khan M, Simunovic N, Ayeni OR (2016) Outcome reporting following navigated high tibial osteotomy of the knee: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 24:3529–3555

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.