



The correlation of sagittal osteotomy inclination and the anteroposterior translation in medial open-wedge high tibial osteotomy—one of the causes affecting the patellofemoral joint?

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Abstract

Purpose For opening-wedge high tibial osteotomy, previous studies have shown that most osteotomies were anterior-inclined. The purpose of this study was to determine the effect of sagittal osteotomy inclination on the anteroposterior translation of osteomized fragments and discuss its possible impact on the patellofemoral joint.

Methods We retrospectively measured the angle between the joint line and the sagittal osteotomy line. We also evaluated the anteroposterior translation of osteomized fragments by measuring the distance from the most posterior point of the tibial plateau to the tibial tuberosity and the anterior cortical line. Correlation between the sagittal osteotomy inclination and the anteroposterior translation of fragments was analyzed.

Results The mean sagittal osteotomy inclination was $6.3 \pm 8.4^\circ$ anteriorly to the joint line and 82% of osteotomies were anterior-inclined. The anteroposterior translation of the osteomized fragments was moderately correlated to the sagittal inclination. Anterior-inclined osteotomy tends to result in the anterior translation of the proximal fragment.

Conclusion High rates of anterior-inclined osteotomy have been described previously as well as in this study. Anterior-inclined osteotomy tends to result in the anterior translation of the proximal fragment. This may result in increased vertical vector force onto the patellofemoral joint, which further accelerates patellofemoral joint degeneration. Therefore, surgeons should attempt to perform parallel osteotomy or avoid anterior displacement of the proximal fragment if there is concern of anterior-inclined osteotomy.

Keywords Osteotomy · Tibial slope · Anteroposterior translation · Patellofemoral joint degeneration

Introduction

High tibial osteotomy (HTO) is a commonly performed procedure for medial unicompartmental osteoarthritis of the knee [5, 7, 9, 13, 18, 34]. This procedure decreases the pressure on the medial compartment of the knee and is efficacious in relieving pain and regenerating cartilage [5, 9, 14, 17–19, 32]. Both closing- or opening-wedge HTO have shown yielded clinical results [4, 6, 15, 28, 33]; however, opening-wedge HTO has become more popular due to reduced soft tissue

dissection and the advancement of internal fixators [8, 31, 34]. Despite the success for relieving symptoms of medial unicompartmental osteoarthritis, more articles have discussed the adverse effect of opening-wedge HTO on the patellofemoral compartment recently [2, 6, 12, 16, 21, 24, 30]. Although controversy exists, the procedure may lead to patellofemoral joint arthritis and patellofemoral pain. This adverse effect has been considered to be the result of the decreased patellar height after the elevation of the tibial joint surface [1, 2, 20], which may increase stress on the patellofemoral joint. However, we wondered if other adjustable factors beyond joint elevation exist that could exert this effect. Lee et al. demonstrated that only 12.9% of open-wedge cases underwent osteotomy parallel to the medial tibia plateau, whereas most osteotomies were anterior-inclined [22]. They also concluded that osteotomies performed in the sagittal inclination exerted an effect on the proximal tibial slope. Thus, we speculated that the sagittal

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inclination may also affect the anteroposterior translation of the osteomized fragments. Translation of the proximal fragment results in the relative position of the knee rotation centre moving to the tibial tuberosity, which can alter patellofemoral contact stress. In this study, we determined the correlation between sagittal osteotomy inclination and the anteroposterior translation of the osteomized fragments. To our knowledge, this is the first study to address this issue.

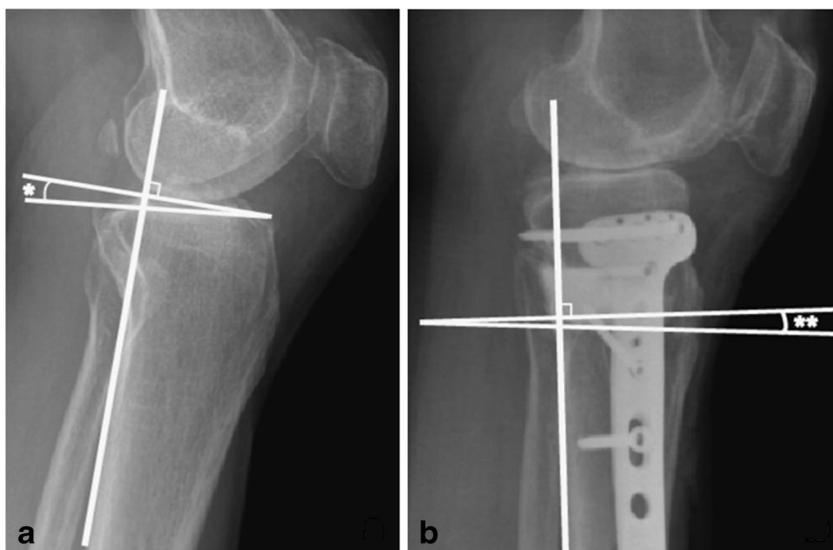
Materials and methods

We performed a retrospective observational study at the corresponding author's hospital. The indications for opening-wedge HTO were as follows: symptomatic medial unicompartamental osteoarthritis, varus knee with a mechanical tibio-femoral angle of at least 5° , and flexion contracture less than 10° . We included those patients who underwent this procedure between January 2012 and November 2017. We reviewed the pre-operative and post-operative plain films. The patients with clearly visible osteotomy lines on the plain films were included. Finally, 69 knees were included. All procedures were performed by the senior author.

Surgical technique

The skin incision was made on the anteromedial side of tibia. A locking plate for the proximal medial tibia was used for fixation of bi-planar supra-tubercle osteotomy. Generally, the detailed steps were the same as described previously [23, 31]. To avoid increasing the proximal tibial slope, we attempted to make an anterior to posterior gap ratio of approximately 1:2 to 2:3 [3, 25, 29]. The aim of the procedure was to align the weight-bearing line through the Fujisawa point [5].

Fig. 1 **a** The angle between the pre-operative joint line and the posterior cortical line. **b** The angle between the osteotomy line and the posterior cortical line



Inclination angle of osteotomy

In order to determine the angle between the sagittal osteotomy and joint lines, we used the posterior cortical line of the proximal tibia as the reference line. The angle A (Fig. 1a) between the pre-operative medial joint line and the reference line was measured as the original proximal tibia slope. Post-operatively, the angle B (Fig. 1b) between the sagittal osteotomy line and the reference line was also measured. The angle between the sagittal osteotomy and the joint line was determined by subtracting angle A from B.

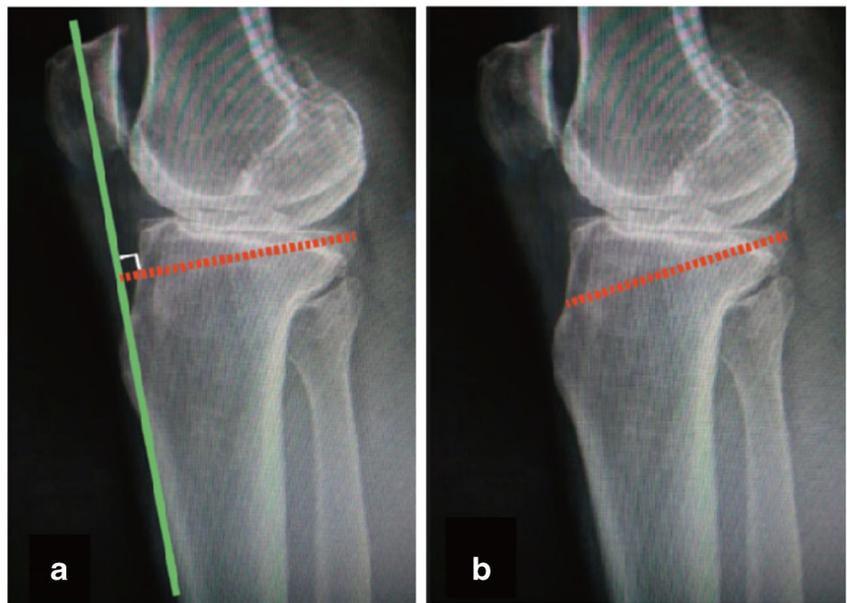
Anteroposterior translation of proximal fragment

For more convincing results, we used two methods to evaluate the anteroposterior translation of the proximal fragment. For the first method, we measured the vertical distance from the most posterior point of the tibial plateau to the anterior cortical line of the proximal tibia. For the second method, we measured the distance from the most posterior point of the tibial plateau to the upmost point of the tibial tuberosity. Since magnification of the pre and post-operative plain films may differ, we calibrated the post-operative value by the lateral patella length. Therefore, the ratio of the post-operative value to the pre-operative value for both methods represents the magnitude of posterior translation of the proximal fragment. A ratio larger than 1 represents posterior translation of the proximal fragment, and vice versa. The absolute distance between the ratio and one represents the extent of translation. The measurement is shown in Fig. 2.

Statistical analysis

All statistical analyses were performed using SPSS version 20 (IBM) on a Microsoft Windows-based computer. The correlation between the sagittal osteotomy inclination,

Fig. 2 The measurement of anteroposterior distance of the proximal tibia. **a** The vertical distance between the most posterior point of the tibial plateau and the anterior cortical line. **b** The direct distance between the most posterior point of the tibial plateau and the upmost point of the tibial tuberosity



anteroposterior translation, and proximal tibial slope was analyzed using Spearman’s rank correlation coefficient.

The current study was approved by the Ethics Committee of the National Taiwan University Hospital with a waiver of informed consent for the retrospective use of patient data (approval number: 201711108RIN).

Results

The mean angle between the sagittal osteotomy line and the joint line was $6.3^\circ \pm 8.4^\circ$ anteriorly. There were 82% anterior-inclined and 18% posterior-inclined osteotomies. The mean value measured by each method for anteroposterior translation

was $0.96 \pm 0.96\%$ and 0.92 ± 0.926 , respectively. A ratio larger than 1 represents posterior translation of the proximal fragment, and vice versa. There were 51 (75%) and 50 (73.5%) anterior translations for each measurement method. The mean change of proximal tibia slope was $-1.7 \pm 4.9^\circ$.

The correlation between sagittal inclination, translation, and change of proximal tibial slope is shown in Table 1. The values measured from both methods were strongly correlated to each other (Spearman’s rank correlation: 0.775, $P < 0.001$). For both methods, there was a moderate correlation (Spearman’s rank correlation -0.423 and -0.419 , $P < 0.001$) between the anteroposterior translation and inclination of osteotomy, respectively, indicating that anterior-inclined osteotomies were prone to experience anterior translation of the proximal fragments.

Table 1 Correlation of the anteroposterior (AP) translation, inclination, and change in proximal tibial slope

| | Inclination | AP translation ¹ | AP translation ² | PTL |
|-----------------------------|-------------|-----------------------------|-----------------------------|--------|
| Inclination | | | | |
| Spearman’s Rho | | -0.423 | -0.419 | -0.351 |
| <i>P</i> | | <0.01 | <0.01 | 0.003 |
| AP translation ¹ | | | | |
| Spearman’s Rho | -0.423 | | 0.775 | 0.166 |
| <i>P</i> | <0.01 | | <0.01 | 0.177 |
| AP translation ² | | | | |
| Spearman’s Rho | -0.419 | 0.775 | | 0.074 |
| <i>P</i> | <0.01 | <0.01 | | 0.551 |
| PTL | | | | |
| Spearman’s Rho | -0.351 | 0.166 | 0.074 | |
| <i>P</i> | 0.003 | 0.177 | 0.551 | |

PTL change of proximal tibial slope

¹ Anteroposterior translation measured by method 1

² Anteroposterior translation measured by method 2

Meanwhile, the change in the proximal tibial slope and sagittal inclination were weakly correlated (Spearman's rank correlation -0.351 , $P=0.003$).

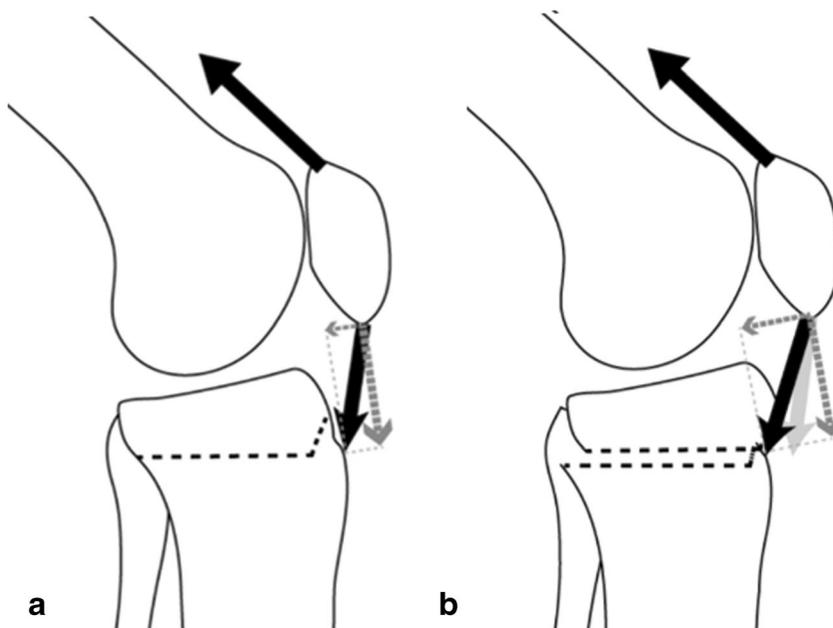
Discussion

The most important finding of this study was that the relative position of the knee rotation centre and tibial tuberosity in the sagittal plane significantly correlated with the sagittal inclination of osteotomy. Anterior-inclined osteotomy tends to move the proximal fragment anteriorly. The possible mechanism is that the direction of the osteotomy opening is usually perpendicular to the sagittal inclination unintentionally. As a result, the anteriorly displaced proximal tibial fragment moves the rotation centre of the knee anteriorly. Under such conditions, tibial tuberosity is relatively posterior, which changes the direction of force transmission via the patella tendon. Therefore, the vertical vector force onto the patellofemoral joint likely increases (Fig. 3). An increased contact force may accelerate cartilage wearing and further arthritis. In the present study, 82% of knees showed anterior-inclined osteotomy, in concordance with a previous study [22]. The high percentage of anterior-inclined osteotomy may be due to the interference of unreleased pes anserine [22, 23]. Consequently, this effect can influence a large portion of patients who undergo opening-wedge high tibia osteotomy. Therefore, surgeons should attempt to perform parallel osteotomy or avoid an anterior displacement of the proximal fragment if there is concern of anterior-inclined osteotomy.

Various studies have reported the adverse effect of opening-wedge osteotomy on the patellofemoral joint [6,

10, 12, 16, 30, 32]. The incidence of anterior knee pain has been reported to be 28% [30]. Second-look arthroscopy also showed significant progression of cartilage degeneration 26 months after operation [16]. Several probable factors which may alter the patellofemoral contact force, such as excessive tibial internal rotation [10] and patella infera [1, 2, 20], have been discussed. Furthermore, patella infera has been considered to be an important cause of increased contact force of the patellofemoral joint. Although this concept was commonly accepted in most studies, there were some controversies. Ihle et al. proposed a novel femur-reference method and showed no change in the patella height [11]. Additionally, a meta-analysis concluded that the patella height was unchanged, as indicated by the Insall-Salvati index (ISI) [1]. We consider there should be causes other than joint elevation, which account for the different results between these indices. The most commonly used patella height measurement indices in previous studies include the ISI, Blackburne-Peel index, and Caton-Deschamps index [1, 11]. As mentioned previously, the ISI may be unchanged since the relative position of the tibial tuberosity and the patella is unchanged in the sagittal plane after osteotomy. The Blackburne-Peel index decreases after opening-wedge osteotomy because the elevated tibial plateau decreases the numerator in this index. However, the Caton-Deschamps index is the ratio between the distance between the lower pole of the patella and the upper limit of the tibia, and the length of the patellar joint surface. Therefore, it may be not only influenced by the elevation of the tibial joint surface, but also the anteroposterior translation of the proximal fragment. Because elevation of the joint surface is inevitable for opening-wedge osteotomy, the anteroposterior translation

Fig. 3 The vector force onto the patellofemoral joint increases after osteotomy. **a** Pre-operative and **b** post-operative



of the osteomized fragments should be well controlled. Due to the significant correlation, avoiding anterior inclined osteotomy may be effective at minimizing adverse effects on the patellofemoral joint.

The proximal tibial slope tends to increase [3, 4, 20, 24, 26, 27]. An anterior to posterior gap ratio of 1:2 to 2:3 has been recommended to prevent this phenomenon [3, 25, 29]. In using this technique carefully, the mean change of the proximal tibial slope was sufficiently controlled in the present study. Recently, the proximal tibial slope was found to be related to the sagittal osteotomy inclination [22]. The correlation between these two parameters was also significant, but weak in the present study. These results showed that the anterior-inclined osteotomy may cause increased proximal tibial slope. We consider that the relatively mal-oriented sagittal cut confuses the surgeons when determining whether the anterior to posterior gap ratio is close to 1:2 or 2:3. When the sagittal cut is anterior-inclined, the surgeon may prefer a ratio of 2:3, rather than 1:2, to have the osteotomy line more visually perpendicular to the tibial axis. Therefore, mal-oriented sagittal osteotomy should be avoided if possible to prevent subsequent mistakes. It requires further studies to generalize the optimal gap ratio for different sagittal osteotomy inclinations.

The study has several limitations. First, we did not analyze clinical outcomes because the post-operative period was short in most patients. However, the findings of this study are novel and may improve surgical processes. Nevertheless, further studies are required to evaluate the clinical relevance. Second, we could not demonstrate that the decreased anteroposterior distance between the tibial tuberosity and rotation centre of the knee truly results in an increased patellofemoral contact force. However, this inference is logical and merits further biomechanical study. Finally, we could only suggest a parallel inclination of osteotomy. Further studies are necessary to clarify the surgical tips to overcome the effect of a mal-oriented inclination.

Conclusion

The present findings confirm the correlation between sagittal osteotomy inclination and anteroposterior translation of osteomized fragments following opening-wedge osteotomy. Changes in the relative anteroposterior position of the tibial tuberosity and rotation centre of the knee may alter the contact force of the patellofemoral joint. Therefore, attempts to avoid a mal-oriented sagittal cut may help decrease the adverse effect of performing opening-wedge osteotomy on the patellofemoral joint.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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