

Patella Height Changes Post High Tibial Osteotomy

Abstract

Background: Medial opening wedge high tibial osteotomy (HTO) is a well-described treatment in early medial compartmental osteoarthritis of the knee. However, two undesirable sequelae may follow –patella baja and changes in the posterior tibial slope (TS). **Materials and Methods:** We conducted a retrospective study in patients who underwent HTO in our center between September 2009 and February 2017. Preoperative and 6-week postoperative long-leg weight bearing films and lateral knee radiographs were assessed. Pre- and postoperative radiological measurements include the Caton-Deschamps Index (CDI), the mechanical axis deviation (MAD), and the posterior TS. Independent *t*-test and Pearson correlation test were performed. **Results:** A total of 106 knees were recruited. The mean age was 48.8 ± 10.8 years. 66 (62.3%) and 40 (37.7%) knees were from males and females, respectively. The mean pre- and postoperative measurements was ($-9.70^\circ \pm 3.67^\circ$ to $0.08^\circ \pm 2.80^\circ$) (–varus; +valgus) for the MAD, ($7.14^\circ \pm 1.78^\circ$ to $8.72^\circ \pm 3.11^\circ$) for posterior TS, and ($0.93^\circ \pm 0.084^\circ$ to $0.82^\circ \pm 0.13^\circ$) for CDI ($P \leq 0.001$ for all). The association between patella height change and the level of osteotomy (supra-tubercle vs. infra-tubercle) was statistically significant ($P < 0.001$). A supra-tubercle osteotomy cut significantly lowering patella height ($P = 0.011$). There was otherwise no statistically significant correlations between patella height changes and the correction angle ($P = 0.187$) or posterior TS change ($P = 0.744$). **Conclusions:** A medial opening wedge HTO above the tibial tubercle was significantly associated with lowering patella height or reducing CDI postoperatively. Based on our results, we would recommend the use of an infra-tubercle osteotomy during the corrective surgery to prevent the complication of patella baja.

Keywords: High tibial medial osteotomy, patella height, posterior tibial slope

MeSH terms: Osteotomy, osteoarthritis, knee, mechanical

Introduction

High tibial osteotomy (HTO) is a well described treatment in early medial compartmental osteoarthritis of the knee.¹⁻⁵ This procedure is especially useful in younger patients to offload the medial compartment of the knee by changing the mechanical axis. However, in the process of doing so, there is always a concern of the two common undesirable effects, namely, the patella height changes and posterior tibial slope (TS) changes post HTO.

Patella baja will lead to changes in the normal kinematics of the knee joint and hence may predispose one, to the development of patellofemoral osteoarthritis.⁶ On the other hand, changes in the posterior TS may have effect on anterior cruciate ligament or posterior cruciate ligament tensile load and alter contact pressure of the tibiofemoral joint.⁷

On top of that, these two changes may also lead to a more challenging total knee arthroplasty in the future.^{8,9}

This study evaluates the correlation between the changes in patella height with several factors in knees that underwent medial opening wedge high tibia osteotomy. The main factors of concern were the level of osteotomy (supra-tubercle cut vs. infra-tubercle cut), degree of mechanical axis correction and change in posterior TS. Besides, we also looked at the relationship of patella height changes with pre- and post-mechanical axis deviation (MAD), pre- and post-posterior TS measurements and type of implant use.

Materials and Methods

We conducted a retrospective study of consecutive patients who underwent medial open wedge HTO in our center between September 2009 and February 2017. We included patients with symptomatic

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medial compartment osteoarthritis of the knee (Grade 1 and Grade 2) and primary tibia vara without evidence of radiographic osteoarthritis but due to unsightly varus deformity. They were from the age group of 18 to 66. We excluded patients with secondary tibia vara due to rickets, metaphyseal-epiphyseal dysplasia, Blount's disease, and previous proximal tibia fractures.

Operative procedure

Preoperative planning determining the angle of correction was crucial. The aim of correction was to achieve a straight mechanical axis line from the head of femur, to the center of knee and to the center of ankle. Biplanar (axial and coronal cut) incomplete open wedge HTO was performed in all knees using the operative technique first described by Staubli *et al.*¹⁰ However, in our study population, the coronal cut was carried out either with a supra-tubercle or infra-tubercle cut. In cases where the correction angle was $<10^\circ$, supra-tubercle osteotomy was performed. On the other hand, if the correction angle was $>10^\circ$, then infra-tubercle osteotomy was performed. Acute correction to the desired angle according to the preoperative planning was opened using staggered osteotome technique. It was then maintained with laminar spreader. Metal wedge or wedge bone graft with corresponding size were inserted into the osteotomy site and was fixed by either a Puddu plate or TomoFix plate [Figure 1].

Radiological measurements

Pre- and postoperative radiographic images at 6 weeks were studied and measured using the Centricity Enterprise Web

V3.0 (8.0.1400.128) (GE Medical Systems Information Technologies, Barrington, IL, USA). Radiographic evaluations were made on long leg weight bearing films and lateral knee films.

Caton-Deschamps Index (CDI)¹¹ was used to measure the patella height [Figure 2]. The CDI is the ratio between the distance from the inferior tip of patella to the anterosuperior angle of tibia, and the length of the patellar articular surface. Ratios >1.3 is known as patella alta; 0.8–1.2 is the normal height; 0.6–0.8 is considered low height; and <0.6 suggests patella baja. The change in patella height was defined as the difference between pre- and postoperative CDIs for this study.

The MAD was measured from the center of the femoral head, to the center of knee and to the center of the ankle [Figure 3]. The correction angle was defined as the difference between the pre- and postoperative MAD.

Posterior TS was defined as the angle formed between the medial tibial plateau and a line drawn perpendicular to the tibial shaft on lateral film of the knee [Figure 4]. Similarly, the TS changes referred to the difference between pre- and postoperative measurements.

Statistical analysis

All data were compiled into Microsoft Excel 2003 (Microsoft Corp., Redmond, WA, USA) and the statistical analysis was performed using Statistical Package for the Social Sciences version 23.0 (SPSS Inc., Chicago, IL, USA).

A descriptive analysis of the sociodemographic characteristics of our cohort was initially done to evaluate

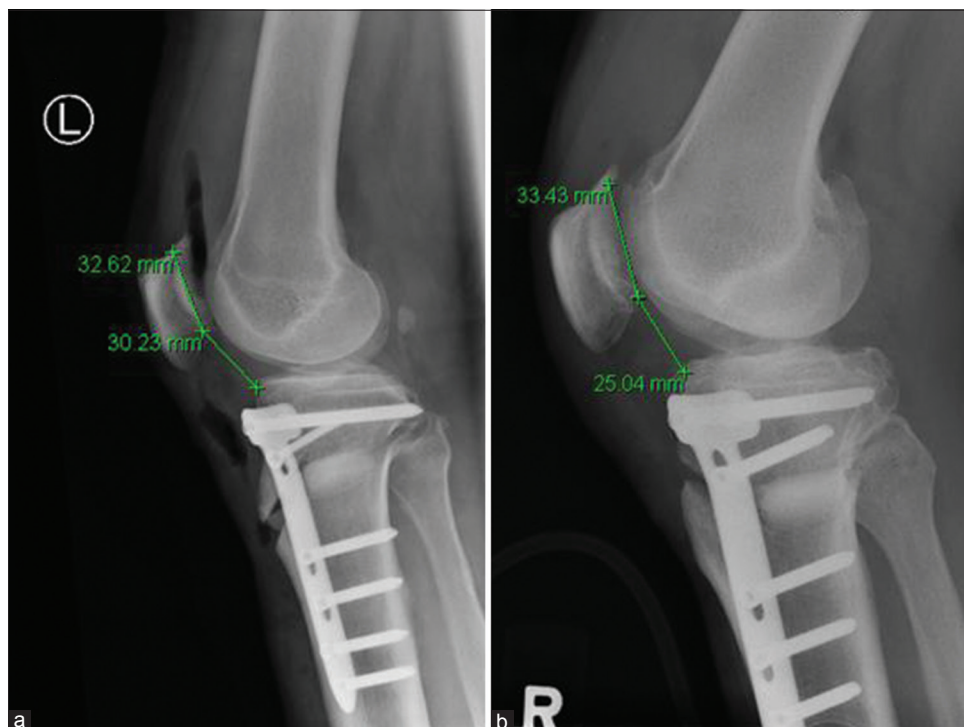


Figure 1: X-ray knee joint lateral views showing (a) Infra-tubercle osteotomy, (b) supra-tubercle osteotomy



Figure 2: X-ray knee joint lateral view showing Caton-Deschamps Index = A/B

the distribution, normality, and homogeneity of the data. Descriptive analysis included frequency and percentage distribution for categorical variables and mean and standard deviation for numerical variables.

Statistical analysis was followed by the independent *t*-test and Pearson correlation test to determine the relationship between patella height changes (preoperative CDI minus postoperative CDI) with the following factors:

- i. Level of osteotomy (supra/intra-tubercle) (ii) Correction angle (pre-MAD - post-MAD) (iii) Changes of TS (pre-TS - post-TS) (iv) Preoperative MAD (v) Postoperative MAD (vi) Preoperative posterior TS in lateral film (vii) Postoperative posterior TS in lateral film (viii) Type of implant used (Puddu/TomoFix plate).

The level of significance was set to be below 0.05.

Results

A total of 121 knees were traced from computerized patient support system. However, only 106 knees (left = 54, right = 52) were finally recruited for this study after all the exclusion. The mean age of our patients was 48.8 ± 10.8 years. 66 (62.3%) knees were from males and 40 (37.7%) knees were from females. The ethnicity was distributed as 81 (76.4%) Chinese, 10 (9.4%) Malay, 5 (4.7%) Indian, and 10 (9.4%) others. 88 (83.0%) patients underwent HTO for the treatment of medial compartment osteoarthritis, and 18 (17.0%) for primary tibia vara. 82 (77.4%) and 24 (22.6%) patients had a supra-

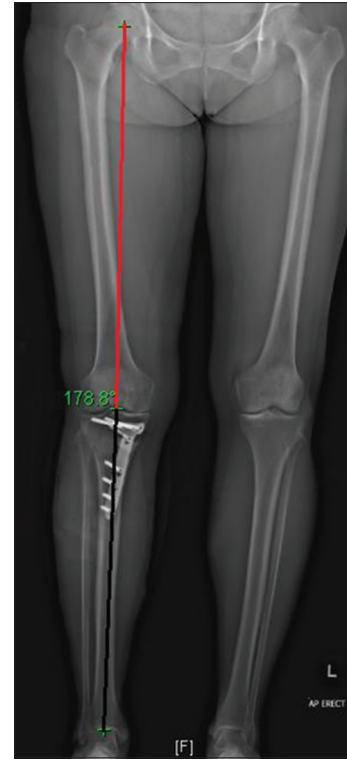


Figure 3: Scanogram both lower limbs showing mechanical axis deviation = angle between line drawn from center of the femoral head to center of the knee, and the line drawn from center of the knee to center of ankle

tubercle and infra-tubercle cut, respectively. These patient characteristics are summarized in Table 1.

The preoperative mean MAD of the knee was $-9.70^\circ \pm 3.67^\circ$ (-varus; +valgus), which improved to $0.08^\circ \pm 2.80^\circ$ after surgery. The mean posterior TS preoperatively was $7.14^\circ \pm 1.78^\circ$, which increased to $8.72^\circ \pm 3.11^\circ$ postoperatively. The mean CDI was $0.93^\circ \pm 0.084^\circ$ preoperatively which reduced to $0.82^\circ \pm 0.13^\circ$ postoperatively. The changes in all three indices pre- and postoperatively were statistically significant ($P \leq 0.001$) [Table 2].

After conducting an independent *t*-test, we found a statistically significant association between patella height change and the level of osteotomy ($P < 0.001$). The mean preoperative CDI in supra-tubercle osteotomy group is significantly higher compare to the mean preoperative CDI in the infra-tubercle osteotomy group. However, the mean postoperative CDI in the supra-tubercle osteotomy group became significantly lower compared to the mean postoperative CDI in the infra-tubercle osteotomy group [Table 3]. On the other hand, there was no significant relationship between patella height change with the correction angle ($P = 0.187$) and with posterior TS change ($P = 0.744$) on correlation analysis [Table 4].

We further classified the CDI into 4 classes (>1.3 = patella alta, $0.8-1.2$ = normal height, $0.6-0.8$ = low height, and <0.6 = patella baja). The pre- and postoperative CDI of our

study population were only distributed into either the normal height or low height classes. There were no cases of patella alta or patella baja. Factors that influenced the postoperative CDI after further classification was consistent with the

findings mentioned above. The supra-tubercle osteotomy was significantly associated with lowering patella height as compared to infra-tubercle osteotomy ($P = 0.011$) [Table 3]. Pre- and postoperative TS, pre- and postoperative MAD, correction angle, and types of implant show no statistically significant in the changes of patella height [Table 5].



Figure 4: X-ray knee joint lateral view showing posterior tibia slope = angle between medial tibial plateau and a line perpendicular to tibia shaft

Table 1: Patient characteristics of 106 knees

Characteristic	Study population (n=106)
Age (mean±SD)	48.78±10.82
Gender, n (%)	
Male	66 (62.3)
Female	40 (37.7)
Race, n (%)	
Chinese	81 (76.4)
Malay	10 (9.4)
Indian	5 (4.7)
Others	10 (9.4)
Site of HTO, n (%)	
Left	54 (50.9)
Right	52 (49.1)
Indication for HTO, n (%)	
Osteoarthritis	88 (83.0)
Primary tibia vara	18 (17.0)
Level of osteotomy, n (%)	
Supra-tubercle	82 (77.4)
Infra-tubercle	24 (22.6)
Type of implant, n (%)	
Puddu	16 (15.1)
Tomofix	90 (84.9)

HTO=High tibial osteotomy, SD=Standard deviation

Discussion

HTO has gained popularity in the treatment of isolated medial compartment osteoarthritis, especially in the younger age group.^{1,5,12} By correcting the mechanical axis, it will allow redistribution of weight and hence off load the medial compartment and assist in cartilage regeneration.^{13,14} However, patella baja is a well-known undesired result following HTO.¹⁵⁻¹⁷ In earlier days, the incidence of patella infera following HTO was reported to be as high as 89% by Scuderi *et al.*¹⁸ There was also a study which showed patella infera following HTO may be correlated with poor functional outcome.¹⁹ Patella baja also lead to a challenging total knee arthroplasty in the future. Exposure of the knee joint would be difficult, especially on eversion of the patella. This increases the risk of patella tendon avulsion. On top of that, the major drawback is the change in the biomechanics of the patellofemoral joint, which may lead to patellofemoral osteoarthritis.^{6,8,9}

Many studies have compared the incidence of patella height changes between open wedge HTO and close wedge HTO.¹⁵ Patellar baja frequently happen with open wedge osteotomies,^{12,20} compared to a high degree of patella

Table 2: Pre and postoperative radiological measurements

Variables	Preoperative	Postoperative	Difference	P
Tibial slope	7.14±1.78	8.72±3.11	1.58±3.19	<0.001
CDI	0.93±0.084	0.82±0.13	0.11±0.12	<0.001
MAD	-9.70±3.67	0.08±2.80	9.77±3.57	<0.001

CDI=Caton-Deschamps Index, MAD=Mechanical axis deviation

Table 3: Association between Caton-Deschamps Index and level of osteotomy

Variables	Level of osteotomy		
	Supra (n=82)	Infra (n=24)	P
Preoperative mean CDI	0.94±0.077	0.89±0.096	0.009
Postoperative mean CDI	0.80±0.13	0.87±0.087	0.018
Mean patella height change	0.13±0.12	0.02±0.09	<0.001

CDI=Caton-Deschamps Index

Table 4: Linear (Pearson) correlation of patella height change and mechanical axis changes and posterior tibial slope changes

Variables	Correction angle		Tibial slope changes	
	PCC, r	P	PCC, r	P
Patella height change	0.13	0.187	0.03	0.744

PCC=Pearson Correlation Coefficient

Table 5: Association between normal patella height and low patella height with other factors

Variables	Postoperative CDI		P
	Normal patella height (CDI=0.8-1.2)	Low patella height (CDI=0.6-0.8)	
Preoperative tibial slope	7.20±1.70	7.07±1.89	0.700
Postoperative tibial slope	8.60±3.32	8.87±2.84	0.660
Preoperative MAD	-9.57±3.38	-9.87±4.06	0.676
Postoperative MAD	-0.08±2.78	0.27±2.84	0.530
Corrective angle	9.49±3.27	10.14±3.95	0.106
Site of osteotomy (%)			
Supra-tubercle	41 (50.0)	41 (50.0)	0.011
Infra-tubercle	19 (79.2)	5 (20.8)	
Side of osteotomy (%)			
Right	27 (51.9)	25 (48.1)	0.340
Left	33 (61.1)	21 (38.9)	
Types of plate (%)			
Puddu	7 (43.8)	9 (56.3)	0.260
TomoFix	53 (58.9)	37 (41.1)	

MAD=Mechanical axis deviation, CDI=Caton-Deschamps Index

elevation produced with closing wedge osteotomies.²¹ This traditionally described medial opening wedge HTO is always cut proximal to the tibial tuberosity or with a corona cut exiting just behind the patella tendon. As a consequence, this increases the distance between the tibia tubercle and knee joint line, resulting in patella baja.

Efforts have been carried out to prevent this undesired consequence of patella baja postmedial open wedge HTO. Gaasbeek *et al.* described a new technique of distal tuberosity osteotomy in open wedge HTO to prevent patella baja.²² Longino *et al.* concluded from his prospective cohort study that combined tibial tubercle osteotomy with medial opening wedge HTO will minimize patellar height changes.²³ Another study by Shim *et al.* observed better functional and radiological outcomes in HTO with infra-tubercle osteotomies.²⁴ On the other hand, El-Azab *et al.* concluded that there was no correlation between the correction in the coronal plane and the changes in the sagittal plane with patella height changes.¹⁷

However to date, factors which may affect the change in patella height is still unclear as the results reported in several studies are inconsistent. Among those that have been described were joint-line elevation, increase TS, patellar ligament shortening due to scarring or immobilization, and magnitude of angle of correction.^{16,20-28} Hence with a fair number of 106 knees, we carried out a retrospective study to look at the possible factors that affect the change in patella height. We utilized the CDI as it was proven to have better reproducibility, and is also a more direct method to measure patella height compared to Insall-Salvati ratio which measures the patella tendon length.²⁹

Our results were consistent with previous studies showing significant reduction in patella height and significant increase in posterior TS postoperatively following open wedge HTO.^{17,26-28} However, the only factor identified

to be statistically significant in affecting the change in patella height was the level of osteotomy. This supports the findings of Gaasbeek *et al.*²² and Shim *et al.*²⁴ In our series of patients, 50% of all knees that underwent supra-tubercle osteotomy had low patella height postoperatively. However, only 20.8% from the infra-tubercle osteotomy group had low patella height postoperatively. For osteotomies performed distal to the tibial tubercle, the tibial tuberosity remained attached to the proximal bony fragment. Therefore, such an approach is unlikely to change the patella height. By performing the infra-tubercle cut, the coronal cut is located away from the patella ligament, as compared to the supra-tubercle cut, which exits just behind the patella ligament. The infra-tubercle cut hence reduces the risk of injury to the patella ligament, which may cause fibrosis, scarring and shortening to the patella ligament.

Many studies have previously reported that posterior TS tend to increase after medial opening wedge HTO,³⁰⁻³³ but its correlation with patella height has not been well studied. In our study, we found that pre- and postoperative TS measurements did not show significant association with postoperative low patella height. The change in tibia slope angle did not show significant correlation with change in CDI as well. This contradicts the results published by Kaper *et al.* and Brouwer *et al.*,^{16,25} in which both authors found a positive correlation between increasing TS angles and lower patella heights. Noyes *et al.* suggested that opening of the anterior gap (the coronal cut of the biplanar osteotomy) should be roughly half to two-thirds the posterior gap (the axial cut of the biplanar osteotomy) so as to prevent changes in the TS.³⁴ As such, we propose that this novel technique as described by Noyes *et al.* should be employed in all cases, be it a supra-tubercle or infra-tubercle osteotomy. This will aim to preserve the posterior TS after surgery.

Similarly, pre- and postoperative MAD value did not show significant association with postoperative patella height.

The corrective angle was not significantly correlated with change in CDI as well. As long as we perform the corrective surgery meticulously, we should not have any undesired results, even if the angle of correction is large. However, infra-tubercle cut is recommended for cases that require $>10^\circ$ correction by Gaasbeek *et al.*²² The type of implants used (Tomofix vs. Puddu) should not affect the changes in CDI as long as proper technique is employed. Both implants are rigid enough to prevent any loss of correction leading to change of patella height.

The main limitation of this study is that it is a retrospective study. Hence, the number of cases undergone supra-tubercle or infra-tubercle osteotomy is not equally distributed. Furthermore, it was based merely on radiological findings and measurements at 6-week postoperative. Thus, a followup study with final functional outcomes evaluation will be more meaningful. Comparison of the clinical and radiological union between these two groups of patients is also important as infra-tubercle osteotomy may have an effect on the delayed union.

Conclusion

We have identified medial opening wedge HTO above the tibial tubercle to be significantly associated with lowering patella height postoperatively, as the mean postoperative CDI in supra-tubercle osteotomy group is significantly reduced. Our results support the use of an infra-tubercle osteotomy during the corrective surgery to prevent patella baja. It will be especially useful for cases that begin with low patella height preoperatively. This has important notions on the outcomes of the patient as patella baja may eventually result in early onset patellofemoral osteoarthritis, and can potentially pose challenges during a total knee arthroplasty procedure in the future. Angle of correction, changes of posterior tibia slope, and types of implants used are not important factors as long as proper surgical techniques are used.

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Conflicts of interest

There are no conflicts of interest.

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