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Original article

Role of constraining staple on tibial slope in open wedge osteotomy: A comparative study

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ABSTRACT

Background: Medial opening-wedge high tibial osteotomy (HTO) corrects varum deformities in osteoarthritic knees. This procedure has been shown to increase tibial slope, which may limit knee extension and provoke an anterior tibial translation. The purpose of this research was to study the impact of a constraining staple on the variation of the tibial slope in medial opening-wedge HTO.
Hypothesis: Insertion of a bone staple on the anterior aspect of the tibia during medial opening-wedge HTO minimizes risks of tibial slope increase.
Materials and methods: This retrospective study was conducted on 91 cases of HTO performed by a single surgeon between 2008 and 2013. Tibial slope was measured pre-operatively and postoperatively according to Brazier's method. We analyzed tibial slope variation in a group that did not receive bone staple insertion during their HTO and compared to the group that did.
Results: A total of 91 patients met the inclusion criteria, 61 males (67.0%) and 30 females (33.0%). The median age was 51 years old. In the staple group, a 0.1° mean increase in tibial slope was found ($p < 0.001$), whereas in the non-staple-inserted group, a 2.4° mean increase in tibial slope was observed ($p < 0.001$).
Discussion and conclusion: The use of a temporary anterior staple during medial-opening HTO appears to be effective in minimizing tibial slope increase.
Level of evidence: III, Retrospective comparative study.

1. Introduction

High tibial osteotomy (HTO) is a well-established procedure for deformity correction in patients with genu varum and medial compartmental knee osteoarthritis. [1] [2] [3] [4]. The purpose of HTO is to correct the angle deformity and obtain a *genu valgum*, unloading the degenerative side of the joint. This procedure tends to decelerate articular cartilage degeneration and delay the need of a total knee arthroplasty by 8 to 10 years or more [5]. It also enables patients to perform intense physical activities.

Two types of HTO are commonly performed: open and closed wedge osteotomies. Closed wedge HTO consists in an osteotomy of the tibia lateral side followed by removal of a bone wedge, whereas opening-wedge is performed by a medial-based bone cut that is spread open and then fixed with a plate. The latter technique, used in this study, has some advantages including no bone resection, no risk of lesions to the peroneal nerve, and it allows for fine adjustments of the angular correction. However, this procedure tends to increase the tibial slope [6], which can result in limited knee extension and/or accentuation of tibial anterior translation, especially in patients with ruptured anterior cruciate ligament. According to the literature, the average tibial slope increase following opening-wedge HTO ranges from less than 1° up to 4°or more [7] [8] [9] [10].

According to Lee YS and al. (2010), in order to reduce the tibial slope increase, the anterior gap needs to be smaller than the posterior gap by approximately 0.67 time [11]. The incision has to be made on the posterior cortex of the tibia and the opening must be performed posteriorly. Noyes et al. (2005) revealed that the opening must be smaller anteriorly than posteriorly [12]. The main purpose of this study was to assess if the insertion of a bone staple on the anterior aspect of the osteotomy during its distraction was effective in minimizing tibial slope modifications. We hypothesized that inserting a bone staple on the anterior aspect of the tibia during medial opening-wedge HTO could be effective at minimizing risks of tibial slope increase.

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Table 1
Cohort demographics.

Male: Female	61:30
Median BMI (range)	30.6 (22 to 48)
Median Age (range)	51 (29 to 63)

BMI: Body Mass Index (kg/m^2).

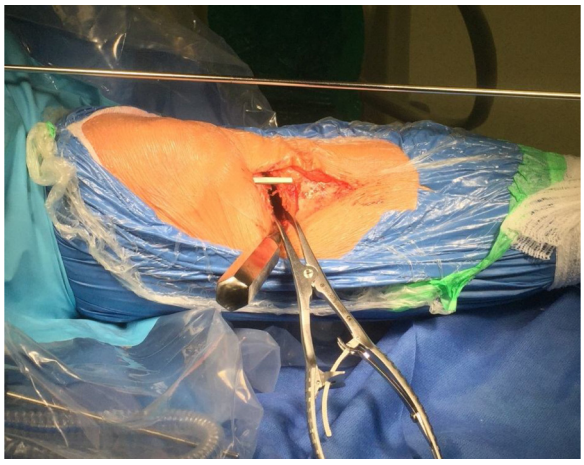

Fig. 1. Insertion of a staple on the anterior aspect of the tibia during medial opening-wedge HTO.

2. Material and methods

2.1. Patients

A retrospective study was carried out on 111 consecutive cases of high tibial osteotomy performed at our institution between 2008 and 2013. The inclusion criterion was the performance of an opening-wedge high tibial osteotomy for medial osteoarthritis. Cases with missing radiographs or without a follow-up up to one year after surgery were excluded. All patients in the control group were operated before January 2013, after what the surgeon started using a temporary staple for all HTO cases. Ninety-one cases were included, 47 patients in the experimental group and 44 in the control group (Table 1). One surgeon (FL) performed all operations. The surgical technique was the same in both groups except for the staple component.

2.2. Surgical procedure

The procedure was performed under fluoroscopic control. Through an anteromedial longitudinal skin incision, the superficial medial collateral ligament was completely divided transversely with the electrocautery while retracting the pes anserinus distally. The osteotomy was performed with an oscillating saw and an osteotome by cutting the tibia from medial to lateral at a level just proximal to the tibial tubercle, aiming at the proximal tibiofibular joint while protecting the posterior structures with a 20-mm bone rasp. The osteotomy was first opened using a screw-driven distractor inserted across the full width of the osteotomy. The angle of correction was verified fluoroscopically using a radiopaque metal rod centered on the femoral head and the talar dome, aiming at the so-called Fujisawa point [13], an intersection of the rod at 62.5% of the width of the tibial plateau from medial to lateral.

In the experimental group, a staple was inserted on the anterior aspect of the tibia after inserting the distractor but prior to the bone spreading (Fig. 1). The surgeon suggests the staple to be positioned on the anteromedial surface of the tibia, centered on and perpendicular to the osteotomy line. This positioning prevents the staple from obstructing the osteotomy fixation with the internal fixation plate. Except for the insertion of a staple in the control group, the procedures were realized in the same indication for both groups.

Once the desired angular correction was obtained, the screw-driven distractor was replaced with a laminar spreader applied on the posteromedial aspect of the osteotomy and the proper alignment of the limb was confirmed on fluoroscopy visualization. Osteotomy fixation was then performed with screws and an internal fixation plate Tomofix ®[1], using the technique recommended by the manufacturer. The staple was removed once all screws were inserted. No bone graft was used, and full-weight bearing was immediately allowed as tolerated.

Table 2
Comparison between the two groups.

	No staple (44)	Staple (47)	*p* value
Age (SD)	49 (7.6)	50 (7.4)	0.57
Male sex (%)	33 (75%)	28 (60%)	0.12
Weight (kg, SD)	93.3 (46.8)	89.1 (45.2)	0.66
BMI (SD)	32.0 (13.9)	31.0 (14.0)	0.88
Variation of tibial slope (degrees, SD)	2.4 (3.1)	0.1(2.7)	< 0.001
Variation of HKA angle (degrees, SD)	11.4 (4.0)	10.0 (6.9)	0.228
Post-operative medial opening (mm, SD)	15.0 (4.4)	12.6 (4.1)	0.008
Medial tibiofemoral OA Grade (median; range)	2 (1;3)	2 (1;3)	0.412
Disruption of lateral hinge (%)	17 (38.6%)	20 (42.6%)	0.704

BMI: Body Mass Index (kg/m^2); OA: Osteoarthritis.

2.3. Evaluation methods

Chart review was done to obtain demographic data, body mass index and weight.

The main focus of this study was to compare the change of tibial slope between the staple group and the non-staple group, but factors previously reported to potentially influence tibial slope variations, such as amount of medial opening, hip-knee-ankle angle (HKA) variation, integrity of the lateral hinge, osteoarthritis (OA) grade, and knee flexion contracture, were also studied [14].

Measures were taken on pre- and postoperative (1 month and 1 year) radiographs with the IMPAX Web1000 software (Agfa-Gevaert, Mortsel, Belgium). Tibial slopes were measured on lateral radiographs of the operated knees using Brazier's method, which is not influenced by the patient's age, sex, weight and height [15]. The tibial slope was obtained by subtracting 90° to the posterior angle. Measurements were performed twice by a single person in a blinded fashion in order to verify their reproducibility. If a one degree or less difference between a measurement of a tibial slope was identified on the same X-ray, the second measurement was used in the data analysis. When the difference was more than one degree, measurements were performed a third time and validated by a second examiner. The tibial slope variation was defined as the difference between the preoperative and the postoperative value. The variation of HKA angle was defined as the difference between the preoperative and the postoperative HKA angle, measured on weight-bearing radiographs of the whole lower limb. Its value was determined by tracing the mechanical axis of the femur (center of the femoral head to the center of the intercondylar notch of the distal femur) and tibia (middle of the tibial spines to the center of the proximal articular surface of the talus).

The medial opening measure was obtained on postoperative radiographs by assessing the length of the distraction on the medial

[1] Depuy Synthes, West Chester, PA, USA ™.

cortex. The modified Ahlbäck classification was used to grade osteoarthritis on preoperative radiographs. [16] The integrity of the lateral hinge was verified on saved operative fluoroscopy images and on one-month follow-up radiographs. Lateral hinge integrity was defined as a continuous lateral cortex. Any cortical discontinuity was considered as a break of the hinge.

2.4. Statistical analysis

Continuous variables are presented as mean, median, minimum, maximum and standard deviation, whereas categorical variables are displayed as count and percentage. Overall descriptive statistics are also presented. Mantel–Haenszel and Chi^2 tests were used to verify the associations between categorical variables. The statistical analysis used Student *t*-test to compare the groups for continuous variables. Linear regression was used to assess influence of variables such as HKA variation, hinge integrity, OA grade, medial opening of the osteotomy, and knee flexion contracture on tibial slope variation and their interaction with the use of a staple. Statistical significance level was set at $p < 0.05$ and confidence interval at 95%. All statistical analysis was performed using SPSS software, v.20.0 (SPSS Inc., Chicago, IL, USA).

The study was approved by our local ethics board. Approval Number: 15.202.

3. Results

Of the 111 cases of high tibial osteotomy studied, twenty patients were excluded, leaving 91 patients for the study. Seventeen patients were excluded because of missing data in their medical file and three patients that had a HTO performed for a diagnosis other than medial osteoarthrosis.

The tibial slope variation was 2.4 ± 3.1 for the non-staple group and 0.1 ± 2.7 for the staple group (Table 2). In the control group,

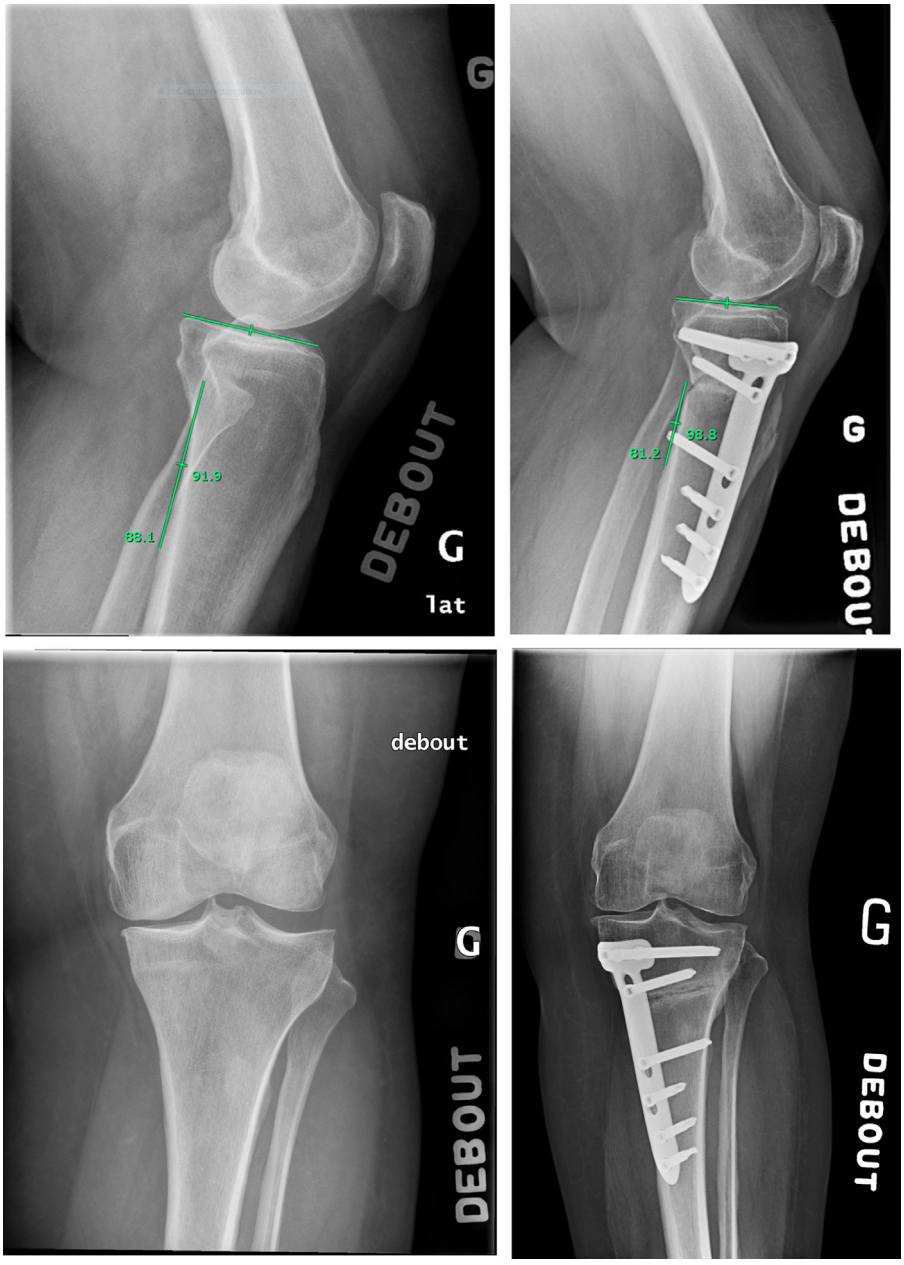

Fig. 2. Effect of high tibial osteotomy performed without the use of a staple on tibial slope seen on preoperative and postoperative radiographs.

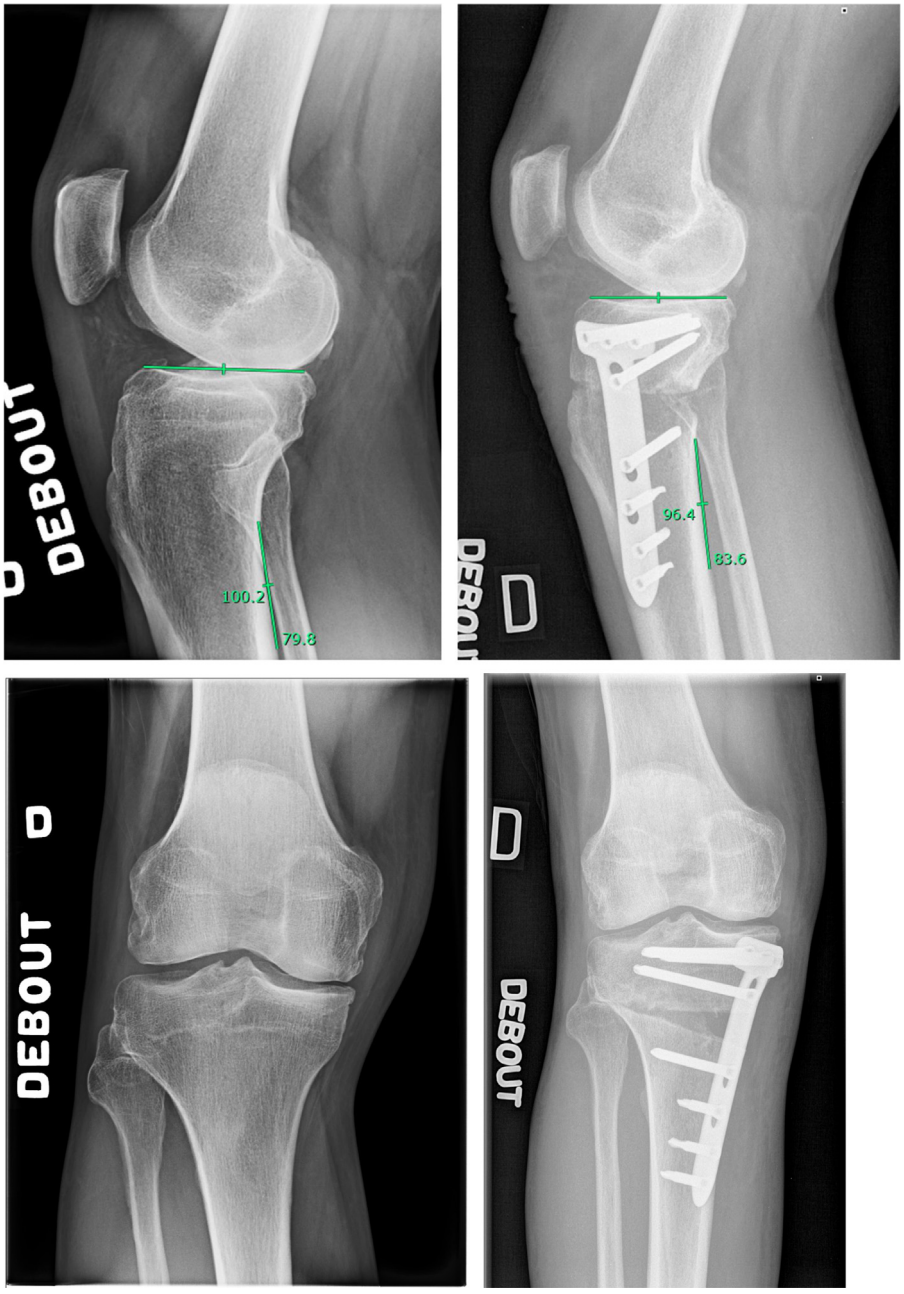

Fig. 3. Effect of high tibial osteotomy performed with the use of a staple on tibial slope seen on preoperative and postoperative radiographs.

post-operative opening was 15.0 mm ± 4.4 and 12.6 mm ± 4.1 for the experimental group, which was significantly less. Age, sex, weight, HKA angle variation, and rate of lateral hinge disruption were not statistically significantly different between the two groups. (Table 2).

Linear regression analysis revealed no statistically significant interaction between tibial slope variation and lateral hinge integrity ($p = 0.497$) nor with HKA variation ($p = 0.424$), OA grade ($p = 0.590$), medial opening of the osteotomy ($p = 0.157$), and knee flexion contracture ($p = 0.747$).

4. Discussion

This study aimed at providing new data on the efficacy of inserting a staple during medial opening-wedge HTO. The most important finding of this study is that the staple group has a lower mean increase of tibial slope compared to the non-staple group (0.1° versus 2.4°, $p < 0.001$). This result could suggest that using a staple during the opening of an osteotomy is effective in minimizing the increase of tibial slope often associated with opening-wedge HTO. (Figs. 2 and 3) Furthermore, the addition of a staple during HTO is not expensive or time-consuming. Patients with disrupted anterior cruciate ligaments or undergoing its reconstruction are most likely to benefit from a better tibial slope control, but other patients too since increased tibial slope is associated with increased odds of postoperative knee flexion contracture.

One possible explanation for the smaller tibial slope variation in the experimental group is related to its significantly smaller medial opening (12.6 mm versus 15.0 mm, $p < 0.05$). If that were the case, however, the tibial slope variation of each group would likely have been proportional to their medial cortical opening measurements. Also, linear regression was nonsignificant regarding the influence

of medial cortical opening on the variation of the tibial slope. It is rather suspected that inserting a staple limits the anterior opening of the osteotomy, resulting in reduced osteotomy gap volume and decreased medial cortical opening. This hypothesis would, however, deserve further testing.

The correlation between the tibial slope and the variation of the HKA was not significant, surprisingly suggesting HKA angle corrections do not affect the variation of the tibial slope in a linear fashion. The surgical technique used in this study may have played a role. An example would be the aggressive division of the superficial medial collateral ligament that may mitigate the potential impact of larger osteotomy openings as posteromedial soft tissue tethers are consequently diminished. Important corrections did not clearly exacerbate the potential adverse effect of open-wedge HTO of increasing the tibial slope, at least with the surgical technique that was used, and the use of a staple as a temporary anterior tether was likely the main factor explaining the difference between the two groups regarding tibial slope variation. Although type-2 error due to a small simple size cannot be excluded, our results suggest that the effectiveness of the staple is not affected by lateral cortex integrity, osteoarthritis stage nor the presence of a preoperative knee flexion contracture.

This study has some limitations that should be considered. First, only one person collected the data. However, that person was blinded to group allocation while performing measurements on radiographs, therefore if measurement errors occurred, they would most likely be systematic and would not decrease the validity of the findings. Second, the efficacy of the surgical technique depended on the positioning of the staple. A detailed explanation of how to position the staple has been provided to allow better reproducibility. Third, the risk error using Brazier's method has been shown to be of three degrees, which is, in regard to the results of this study, considerably high. However, as mentioned previously, if there were errors of the measurements, they would most likely be systematic and would not decrease the validity of the findings. Fourth, this original study is retrospective, which might be a potential source of selection bias.

5. Conclusion

The use of a temporary anterior staple during the distraction step of an open-wedge HTO is a simple and straightforward technique that appears to be effective in minimizing the increased tibial slope often caused by the procedure.

Disclosure of interest

The authors declare that they have no competing interest.

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Authors' contribution

Lavoie, Frédéric: Principal investigator, conceived and designed the analysis, collected the data, wrote the paper.

Gastineau, Cynthia: Second author, contributed data, performed the analysis, wrote the paper.

Denis, Antoine: Third author, wrote the paper, contributed data and performed the analysis.

Al-Shafka, Fidaa: performed the analysis, reviewed and designed the statistical analysis.

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