

Tibial slope and patellar height changes following high tibial osteotomy (a comparative study)

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Received: 17 January 2015 / Accepted: 2 March 2015 / Published online: 12 March 2015
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Abstract

Background Improving the accuracy of high tibial osteotomy not only in the coronal plane but with considering it as a three dimension procedure can give better long term results in cases of medial compartment osteoarthritis associated with varus deformity and minimize the obstacles faced in future total knee replacement (TKR).

Design Two different techniques of high tibial osteotomy: the opening wedge (OWO) and the hemicallotasis osteotomy (HCO) were compared clinically in a prospective randomized clinical trial that was held in Ain Shams University hospitals in the period from December 2010 to April 2013 on thirty knees of twenty-four patients suffering from medial compartment osteoarthritis associated with varus deformity. The patients were allocated randomly (single-blinded) in two groups; where fifteen knees of group (I) underwent high tibial osteotomy using the OWO technique, while those of group (II) underwent the procedure using the HCO technique. Two important parameters were compared; the posterior tibial slope in lateral radiographs using the anatomical proximal tibial axis and the patellar height using the Caton&Deschamps method; to assess the accuracy of the procedure in the sagittal plane.

Results OWO had proven lower accuracy than HCO as regard the change in tibial slope ($P=0.001$ and 0.3 respectively), while both techniques preserved patellar height almost unchanged with optimizing the procedures' techniques ($P=0.4$ and 0.6 respectively).

Conclusion HCO technique for osteoarthritic knees associated with varus deformity can give more accurate results for the sagittal limb alignment and this may improve the long term results of the procedure and facilitate future TKR.

Keywords Osteoarthritis · Total knee replacement · High tibial osteotomy

Introduction

Osteoarthritis (OA) is the most common joint disease, causing a major burden on the community either by limiting the productivity of the individual or by the high medical and surgical costs involved in such a lifelong problem [1]. To date, no intervention has been proven to alter the course of knee OA. Thus, total knee replacement (TKR) has become the most accepted surgical treatment option for end-stage knee OA. Thus, many studies have investigated new interventions and have attempted to improve the present techniques used to manage knee OA at its earlier stage [2].

High tibial osteotomy (HTO) is a well-established procedure for treating varus knees and medial OA in young patients. This procedure has been widely accepted since Coventry [3] first performed osteotomy proximal to the tuberosity. HTO can correct the abnormalities in the coronal plane associated with medial compartment OA, with good to excellent results for up to 10 years following surgery, but unfortunately, these results cease dramatically with time [4–7]. In the last decade, many researchers have reported changes in the sagittal

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plane associated with such a procedure [2, 8, 9] and proposed that such changes should be controlled to obtain better long-term results [8, 10].

The lateral closing wedge technique leads to posterior displacement of the tibia and is associated with a decrease in the tibial posterior slope [8, 10, 11], leading to increased stability of the knee with anterior ligamentous insufficiency, whereas opening wedge osteotomy (OWO) is inherently associated with anterior translation of the tibia and an increase in the tibial posterior slope [8, 10, 12, 13], adding stability to posteriorly unstable knees. These biomechanical observations can be utilized to expand the applications of HTO in varus OA knees with ligamentous insufficiency [14, 15].

However, the effects of different techniques of HTO on the patellar height are still debatable with studies suggesting that it has an important effect on patellofemoral articulation, which can be an obstacle during future TKR procedure [10, 16–18]. Patella baja is associated with OWO and mostly occurs due to retropatellar tendon adhesions. It can be eliminated by early knee range of motion with flexion-extension exercises [19].

Turi [20] reported hemicallotaxis osteotomy (HCO), which depends on the gradual correction of the varus deformity based on the principles of distraction osteogenesis. As the osteotomy was performed below the tibial tuberosity, no changes were observed in the patellar height or the tibial posterior slope; however, less soft tissue scarring and proximal tibial distortion were noted [2, 21].

Hence, the aim of our study was to compare both OWO and HCO techniques with respect to their clinical outcomes, patient satisfaction, and radiological outcomes in cases of medial arthritic varus knees. We have hypothesized that both techniques have the same effect on tibial slope and patellar height.

Materials and methods

A prospective randomized (pilot) comparative clinical study was conducted in the Ain Shams university hospitals between December 2010 and April 2013. The study included 24 patients with 30 knees having varus deformity with either radiological or clinical OA (medial joint pain with a Western Ontario and McMaster Universities, WOMAC, score more than 37).

The patients were randomized either to an open-wedge HTO (OWHTO) (group I) or HCO (group II). The patients were randomly numbered, and the odd-numbered patients were allocated to group I (12 patients), and the even-numbered patients were allocated to group II (12 patients). All the operations of the enrolled cases were performed by the same team of surgeons.

Inclusion criteria

Active patients, including both males and females, with pain in the medial aspect of the knee and hip-knee-ankle varus malalignment (mild patellofemoral pain was not an exclusion criterion) were included in the study. Additionally, the patients were aged between 18 and 65 years, and their knees had a range of not less than 10–100°, with no significant instability, and the varus deformity of isolated tibial origin.

Exclusion criteria

Inactive patients aged above 70 years, with evidence of open growth plate, and suffering from aseptic necrosis of the knee, bone-healing disorders, flexion contracture over 10°, or knee flexion under 100° were excluded from the study. Additionally, patients having significant instability, inflammatory arthritis, arthritis in the lateral compartment, and varus deformity of combined femoral and tibial origin were also excluded.

Of the total patients included in the study, 19 were males (79%), and 5 were females (21%). Group I included 10 males (83%) and 2 females (17%) while group II included 10 males (77%) and 3 females (23%), as one male patient was allocated to group I, then reallocated to group II.

The mean age of all the patients at time of surgery was 37 years (ranging from 21 to 56 years). The mean age of patients in group I was 40±12 years (ranging from 24 to 56 years) and in group II was 34.4±11.5 years (ranging from 21 to 54 years). The procedure in the young patients (below 30 years) was performed for either the radiological evidence of arthritis or clinical symptomatic medial joint pain with WOMAC score of functional impairment. It was associated either with severe deformity (Blount disease in one bilateral case) or post improper fixation of fracture proximal tibia with varus deformity and penetrating screws in the joint (one case). On the other hand, the inclusion of the patients older than 50 years in the study was due to the importance of sitting on the knees and squatting positions for most of our patients in the Middle East area. Hence, we always try to postpone knee replacement in elderly patients above 60 years, provided that the arthritis is confined to the medial compartment.

Of the total patients, nine had undergone HTO on their right knees, and nine had undergone operation on their left knees while six patients had bilateral HTO on their both knees. Group I included four patients who were operated only on their right knees, five only on left knees, and three patients on both knees. Group II included six patients who were operated on their right knees, five only on left knees, and two patients who were operated on both their knees, which were done at the same session.

The degree of OA of the patients was assessed using the WOMAC Index of OA both preoperatively and postoperatively. According to their scores, the patients were graded

from 0 to 5. The preoperative analysis of all knees revealed that 21 knees (11 in group I and 10 in group II) had poor function and 9 knees (4 in group I and 5 in group II) had bad function.

The preoperative varus deformity was assessed for all patients who were graded accordingly into mild (less than -5°), moderate (-5° to -10°), and severe (more than -10°). Of the total knees, 2 knees had mild varus, 20 knees had moderate varus, and 8 knees had severe varus deformity. In group I, 2 knees had mild varus, 12 had moderate varus, and 1 had severe varus. In group II, no knees had mild deformity, 8 knees had moderate varus, and 7 knees had severe varus deformity.

The preoperative tibial slope and patellar height were measured for all the knees (lateral view) using the anatomical proximal tibial axis and the Caton and Deschamps methods, respectively (Fig. 1).

The mean preoperative tibial slope for group I was $7.3^\circ \pm 1.9^\circ$ (range 5° – 11°) and for group II was $8^\circ \pm 2.29^\circ$ (range 5° – 13°). The mean preoperative patellar height for group I was 0.8 ± 0.07 (range 0.72–1) while in group II, it was 0.9 ± 0.1 (range 0.7–1.2). After the operations, the data were reassessed to compare the effect of both techniques on the measurements.



Fig. 1 Lateral view of knee showing measurement of tibial slope angle using proximal tibial anatomical axis and patellar height using Caton and Deschamps technique

Only patients with mild deformity with a WOMAC score less than 37 (good knee function) who have undergone a trial of conservative treatment of physiotherapy for strengthening muscle exercises, lateral shoe wedge and chondroprotective drugs for 6 months. The operation is indicated whenever the knee function based on WOMAC score (above 37) has deteriorated.

The correction angle on the coronal plane was calculated depending on the fixed point correction of the mechanical axis so as to pass through the Fujisawa point along the tibial plateau. This indicated a valgus overcorrection of the mechanical limb axis.

For group I, OWHTO (Fig. 2) was performed using the biplanar osteotomy technique. This was followed by fixation in two cases using the spacer plate with metal block and the rest cases using the conventional T-plates. Iliac bone graft was used in nine cases, and bone substitute was used in six cases.



Fig. 2 Postoperative lateral view (group I): tibial slope after OWHTO

For group II, HCO (Fig. 3) was performed on the patients using infra-tubercle osteotomy, and all of them were fixed using the ring external fixator (Ilizarov frame). Fibular osteotomy was required in all the cases. Gradual correction was started 7 days after the operation at a rate of 0.25 mm/6 h till the desired correction was obtained. After the evidence of consolidation, the frame was removed gradually, allowing for dynamization of the frame.

Statistical analysis

The data was collected, tabled, and statistically analyzed using the Statistical Package for Social Science (SPSS, version 15.0.1).

Descriptive statistics:

1. Parametric data were expressed as a range (minimum and maximum), mean, and standard deviation (\pm SD).
2. Nonparametric data were expressed in terms of frequency and percentage.

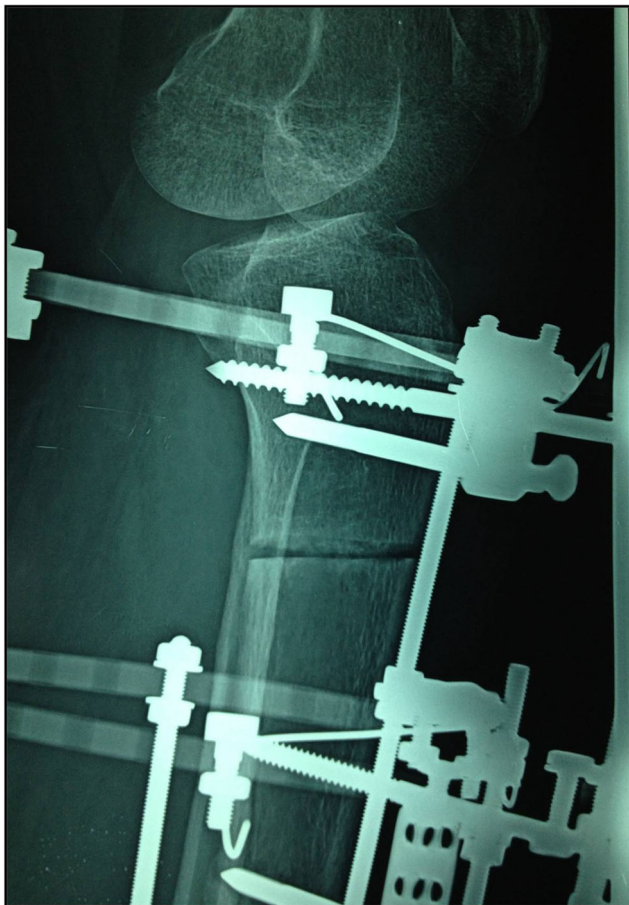


Fig. 3 Postoperative lateral view (group II): tibial slope after HCO

Analytical statistics:

1. Paired *t* test was used to assess the statistical significance of the difference between the two means of one quantitative variable measured twice for the same study group.
2. Unpaired *t* test was used to assess the statistical significance of the difference between the two means of one quantitative variable of two groups.
3. Chi-square test was used for comparing the nonparametric data between the two groups.

The two-tailed *p* value of >0.05 was considered statistically insignificant, $p \leq 0.05$ was considered statistically significant, and $p \leq 0.01$ was considered highly statistically significant.

Results

The mean preoperative and postoperative WOMAC index in group I was 57.7 ± 5.2 (range 50–67) and 25.6 ± 4.5 (range 20–33), respectively, with a *p* value <0.0001 . However, in group II, the mean WOMAC index was 59.3 ± 6.8 (range 50–70) and 25.3 ± 4.6 (range 18–35) with a *p* value <0.0001 . The mean preoperative and postoperative tibiofemoral angle in group I was $-7.06^\circ \pm 2.4^\circ$ (range from -12° to -3°) and $7.4^\circ \pm 1.06^\circ$ (range from 6° to 9°), respectively, with a *p* value <0.0001 . In group II, the mean preoperative tibiofemoral angle was $-11.06^\circ \pm 4^\circ$ (range from -19° to -5°), which was corrected postoperatively to $7.6^\circ \pm 0.9^\circ$ (range 5° – 9°) with a *p* value <0.0001 .

Postoperatively, the tibial slope in group I changed from a mean of $7.3^\circ \pm 1.9^\circ$ (range from 5° to 11°) to $10^\circ \pm 3.3^\circ$ (range from 6° to 18°) with a *p* value of 0.001. In group II, the mean preoperative tibial slope was $8^\circ \pm 2.29^\circ$ (range 5° – 13°), which changed to $8.4^\circ \pm 2.1^\circ$ (range 5° – 14°) postoperatively with a *p* value of 0.3. The patellar height in group I also changed from 0.8 ± 0.07 (range 0.72–1) to 0.8 ± 0.09 (range 0.67–1) with a *p*

Table 1 Preoperative and postoperative results for group (I)

	Preoperative	Postoperative	<i>t</i>	<i>p</i>
WOMAC (96) Mean \pm SD	57.7 ± 5.2	25.6 ± 4.5	35.3	0.00**
Angle ($^\circ$) Mean \pm SD	-7.06 ± 2.4	7.4 ± 1.06	20.4	0.00**
Slope ($^\circ$) Mean \pm SD	7.3 ± 1.9	10 ± 3.3	4.2	0.001**
Patellar height (ratio) Mean \pm SD	0.8 ± 0.07	0.8 ± 0.09	0.7	0.4

WOMAC Western Ontario and McMaster Universities Arthritis Index, SD standard deviation

** $p < 0.01$ is highly significant

* $p \leq 0.05$ is significant

$p > 0.05$ is not significant

value of 0.4 (Table 1). In group II, the mean preoperative patellar height was 0.9 ± 0.1 (range 0.7–1.2) that changed to 0.9 ± 0.11 (range 0.8–1.29), with a p value of 0.6 (Table 2).

Discussion

Although many studies are available on HTO outcomes, it is difficult to compare and pool the results because of the different evaluation systems and techniques used in those studies [22]. Due to the lack of randomized controlled trials, there is no appropriate scientific evidence regarding HTO outcomes. However, it is a common experience that HTO is a reliable and precise surgical procedure for medial arthritis of the knee with proper patient selection [22, 23].

To the best of our knowledge, this current study is the first randomized clinical trial in which OWHTO with acute correction of varus deformity and internal fixation has been compared with the HCO technique with gradual correction of deformity and external fixation.

The mean preoperative WOMAC index [24] for both the groups showed no significant difference ($p=0.4$); however, the postoperative values had significantly improved with no statistical difference between both groups ($p=0.8$). These results indicate that both the techniques are effective methods for improving the clinical condition and functional status of the patients (Table 3).

Gaasbeek et al. [25] compared the opening and closing wedge techniques and reported a preoperative WOMAC index of 51.9 ± 18.5 and 46.5 ± 14.9 for both groups, respectively. They reported an improved postoperative WOMAC index value of 20.0 ± 19.4 and 16.0 ± 15.0 , respectively, for both groups, with a statistically significant difference. All of their patients suffered from less pain and were significantly satisfied with the treatment.

Table 2 Preoperative and postoperative results for group (II)

	Preoperative	Postoperative	I	p
WOMAC (96) Mean \pm SD	59.3 ± 6.8	25.3 ± 4.6	23.2	0.00**
Angle ($^{\circ}$) Mean \pm SD	-11.06 ± 4	7.6 ± 0.9	18.5	0.00**
Slope ($^{\circ}$) Mean \pm SD	8 ± 2.29	8.4 ± 2.1	1.06	0.3
Patellar height (ratio) Mean \pm SD	0.9 ± 0.1	0.9 ± 0.11	0.4	0.6

WOMAC Western Ontario and McMaster Universities Arthritis Index, SD standard deviation

** $p < 0.01$ is highly significant

* $p \leq 0.05$ is significant

$p > 0.05$ is not significant

Table 3 Postoperative clinical and radiological characteristics of both groups

	Group (I) ($n=15$)	Group (II) ($n=15$)	t	p
WOMAC (96) Range	20–33	18–35	0.18	0.8
Mean \pm SD	25.6 ± 4.5	25.3 ± 4.6		
Angle ($^{\circ}$) Range	6–9	5–9	3.09	0.004**
Mean \pm SD	7.4 ± 1.06	7.6 ± 0.9		
Angle correction Range	10–21	12–28	3.3	0.002**
Mean \pm SD	14.5 ± 2.7	18.6 ± 3.9		
Slope ($^{\circ}$) Range	6–18	5–14	1.5	0.12
Mean \pm SD	10 ± 3.3	8.4 ± 2.1		
Patellar height (cm) Range	0.67–1	0.8–1.29	2.7	0.01**
Mean \pm SD	0.8 ± 0.09	0.9 ± 0.11		

WOMAC Western Ontario and McMaster Universities Arthritis Index, SD standard deviation

** $p < 0.01$ is highly significant

* $p \leq 0.05$ is significant

$p > 0.05$ is not significant

Tibiofemoral angle correction

With respect to the coronal plane deformity, the mean corrected angle for both groups was 14.5 ± 2.7 and 18.6 ± 3.9 , respectively. The preoperative and postoperative tibiofemoral angles indicated that both methods can achieve reliable and accurate correction, and a larger correction angle can be obtained in the HCO group.

The postoperative correction angle is a debatable issue as it has a tendency toward hypercorrection for improving the clinical condition of patients. In the study of Gaasbeek et al. (2010) [25], the preoperative tibiofemoral angle for the open-wedge group (25 patients) was $-4.3 \pm 2.2^{\circ}$ and for close-wedge group (25 patients) was $-4.1 \pm 2.1^{\circ}$ that was corrected to $3.8 \pm 2.2^{\circ}$ and $4.4 \pm 2.7^{\circ}$, respectively.

Ribeiro et al. [26] studied 20 patients with a mean preoperative angle of $-8.1 \pm 3.1^{\circ}$ using the OWHTO technique. They reported a mean postoperative angle of $3.4 \pm 3.3^{\circ}$ with a mean correction of 11.5° .

Kolb et al. [27] studied OWHTO in 51 patients using a low profile locked plate. They reported a mean preoperative femorotibial angle of -2.7° (mechanical -9.5°) and a mean postoperative angle of 9.2° (mechanical 2.1° valgus).

Shiha et al. [28] used the Ilizarov gradual correction on 11 patients and corrected the mean preoperative femorotibial angle of 193° to a postoperative mean angle of 171° (9° of anatomical valgus) with an overall mean correction of 17° .

Magyar et al. [29] compared HCO with the closed wedge technique. They corrected the mean preoperative femorotibial angle of 173° (range 165° to 179°) of 25 patients of the HCO group to a mean of 184° (range 181° to 188°). They further

reported an overall 4° valgus angle with an average correction angle of 12°.

Effect on tibial slope

In our study, the preoperative tibial slope angle was not significantly different between both groups. It was also not significantly different for both the groups postoperatively. However, the results for the OWHTO group were significantly increased postoperatively compared to that of the HCO group.

The proximal anteromedial tibial cortex, viewed in cross section, has an oblique shape forming an angle of $45\pm 6^\circ$ with the posterior margin of the tibia, whereas the lateral tibial cortex is nearly perpendicular to the posterior margin of the tibia. Hence, due to these anatomical features, the medial OWHTO increases the tibial slope only if the anteromedial and posteromedial gaps are equal. However, the slope does not change if the anteromedial gap is smaller than the posteromedial gap.

A decrease in the posterior tibial slope caused by the lateral closing wedge osteotomy [8] causes hyperextension and overload on the posterior cruciate ligament (PCL), which contributes to a reduction in anterior instability. As the medial OWO increases the posterior slope, it restricts extension and causes overload on the anterior cruciate ligament (ACL) [10].

In the knees with cruciate ligament insufficiency, increases in the tibial slope during HTO may be useful in PCL insufficiency as it reduces the posterior translation. However, a reduction of the tibial slope may be useful in the knees with ACL insufficiency as it reduces anterior translation [2].

Accordingly, open-wedge osteotomy is recommended for the knees with chronic PCL injuries and posterolateral instability that has been inversely correlated with posterior tibial slope. Care should be taken to restrict the posterior tibial slope to $\geq 10^\circ$ because the load on the ACL can increase by more than 3 times in this case. The anterior opening gap should be 67 % of the posterior gap in order to maintain the posterior tibia slope [10].

Yanasse et al. [13] in their retrospective case series on 31 arthritic varus knees that had undergone medial opening wedge found an average increase in tibial slope of 2.38° . The mean preoperative and postoperative tibial slope angles and standard deviations (\pm SD) were $8.96^\circ\pm 2.83^\circ$ and $11.35^\circ\pm 2.83^\circ$, respectively. This was a significant increase in the tibial slope angle, but it had insignificant clinical effect.

Noyes et al. [30] calculated the effect of the opening wedge angle of medial HTO on the posterior tibial slope and stated that if the anteromedial gap is half of the posteromedial gap, the tibial slope does not change. They further reported that for each increase of 1 mm in the anterior gap, there is an increase of 2° in the posterior tibial slope.

Marti et al. [31] reported that for every 10° of varus correction by HTO, there is an average increase of 2.7° in the posterior tibial slope and 6 mm in the anterior tibial translation.

Nakamura et al. [21] compared the effects of dome osteotomy with OWHTO with HCO and found a mean decrease in posterior tibial slope of 5.9° with the former technique and 0.8° with hemicallotaxis 1 year after surgery. Some authors have suggested that OWHTO with hemicallotaxis and external fixator is the ideal treatment for correcting malalignment of the lower limbs [2, 8].

Effect on patellar height

In our study, no significant difference between the preoperative and postoperative patellar heights was found in each group. We have used the Caton and Deschamps method because it represents the patellar height that might change due to elevation of the proximal fragment. This method indicates narrowing of the medial joint space rather than patellar tendon length, which should not change as the procedure does not affect it.

Some authors believed that the lateral closing wedge HTO is associated with a high incidence of postoperative patella baja. This undesirable effect may lead to the association between anterior knee pain and patella baja and makes the subsequent conversion of the lowered patellar height to TKA technically difficult [16].

Wright et al. [17] research indicated that the changes in osseous architecture after lateral closing wedge osteotomy increases patellar height, whereas the medial OWO lowers patellar height by raising the tibiofemoral joint line. Patellar height declined after medial opening wedge HTO in the absence of any patellar ligament shortening. The Blackburne and Peel ratio changed from 0.75 ± 0.13 to 0.53 ± 0.15 while the preoperative and postoperative Insall-Salvati ratios were 0.96 ± 0.12 and 0.97 ± 0.15 , respectively. The incidence of patella baja raises concerns regarding its potential adverse impact on patellofemoral biomechanics as well as the outcome of subsequent TKA.

Lateral closing wedge osteotomy causes an elevation of the tibial tuberosity due to shortening of the proximal tibia during the procedure, which increases patellar height and is useful for patella baja. Medial OWO causes a decrease in patellar height because the tibial tuberosity is lowered due to the opening of the proximal tibia during the procedure [10].

Lee et al. [32] reported no significant change in the patellar length according to the Insall-Salvati ratio (preoperative and postoperative results were 1.03 ± 0.11 and 1.09 ± 0.11 , respectively).

Kolb et al. [27] found highly significant change in the patellar height with the mean preoperative and postoperative Blackburne and Peel ratios of 0.82 (range 0.75 to 0.9) and 0.75 (range 0.6 to 0.75), respectively ($p<0.001$). While using the Insall-Salvati ratios, the mean preoperative and postoperative ratios were 0.99 (range 0.9 to 1.1) and 1.01 (range 0.9 to 1.2), respectively ($p=0.094$), with no significant change.

Takeuchi et al. [19] studied 57 knees that had undergone OWHTO and reported no change in the patellar tendon length and height. On using the Insall-Salvati ratio, the preoperative and postoperative ratios were 1.0 ± 0.1 . They further recommended the patients to carry out range-of-motion exercises to the maximum flexion, from an early stage after surgery.

Nakamura et al. [21] found no change in the patellar height and patellar tendon length after HCO. In their study, osteotomy was inferior to tibial tuberosity as the preoperative and postoperative patellar tendon lengths were 0.93 and 0.94, respectively.

According to our technique of OWHTO, with the release of superficial medial collateral ligament, the distal fragment moved to valgus while the proximal fragment did not get elevated. Moreover, the early range of motion that protected the patellar tendon from undesirable effects of adhesions and shortening did not change the patellar height. It also did not narrow the medial joint space and provided better biomechanical effects on the medial joint cartilage and better ligamentous balance. However, further studies are required to assess these results.

Limitations of the study

The study has a short-term follow-up, and hence, there is a need for longer follow-up to further assess the effect of both techniques on the patellar height and tibial slope, maintenance of the valgus angle, and the long-term clinical satisfaction of the patients.

The method of fixation in group I was not standardized due to socioeconomic obstacles. Therefore, the effect of using rigid locked plates was not assessed with regard to the stability of the osteotomy, early weight bearing, and need for bone graft. We also faced the same problem when choosing the bone graft (iliac or bone substitutes of different types).

Conclusion

Our findings indicate that the HCO technique has the best effect on the slope angle and that a good understanding of the gap issue might minimize the effect of OWHTO on the slope angle. Moreover, both the procedures had no significant effect on patellar height.

References

- Lawrence RC, Felson DT, Helmick CG, Arnold LM, Choi H, Deyo RA, Gabriel S, Hirsch R, Hochberg MC, Hunder GG, Jordan JM, Katz JN, Kremers HM, Wolfe F (2008) National Arthritis Data Workgroup. *Arthritis Rheum* 58(1):26–35

- Gunes T, Sen C, Erdem M (2007) Tibial slope and high tibial osteotomy using the circular external fixator. *Knee Surg Sports Traumatol Arthrosc* 15:192–198
- Coventry MB (1965) Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. *J Bone Joint Surg Am* 47:984–990
- Rossi R, Bonasia DE, Amendola A (2011) The role of high tibial osteotomy in the Varus Knee. *J Am Acad Orthop Surg* 19:590–599
- Vittorio F (2002) Open wedge high tibial osteotomy. *Tech Knee Surg* 1(1):43–53
- Hernigou P, Medevielle D, Debeyre J, Goutallier D (1987) Proximal tibial osteotomy with varus deformity. A ten to thirteen year follow-up study. *J Bone Joint Surg Am* 69:332–354
- Poignard A, Flouzat Lachaniette CH, Amzallag J, Hernigou P (2010) Revisiting high tibial osteotomy: fifty years of experience with the opening-wedge technique. *J Bone Joint Surg Am* 92(2):87–95
- Savarese E, Bisicchia S, Romeo R, Amendola A (2011) Role of high tibial osteotomy in chronic injuries of posterior cruciate ligament and posterolateral corner. *J Orthopaed Traumatol* 12:1–17
- Ozkaya U, Kabukçuoğlu Y, Parmaksizoğlu AS, Yeniocak S, Ozkazanli G (2008) Changes in patellar height and tibia inclination angle following open-wedge high tibial osteotomy-. *Acta Orthop Traumatol Turc* 42(4):265–271
- Lee DC, Byun SJ (2012) High tibial osteotomy. *Knee Surg Relat Res* 24(2):61–69
- Hohmann E, Bryant A, Imhoff AB (2006) The effect of closed wedge high tibial osteotomy on tibial slope: a radiographic study. *Knee Surg Sport Traumatol Arthrosc* 14:454–459
- Giffin JR, Stabile KJ, Zantop T, Vogrin TM, Woo SL, Harner CD (2007) Importance of tibial slope for stability of the posterior cruciate ligament-deficient knee. *Am J Sports Med* 35:1443–1449
- Yanasse RH, Cavallari CE, Chaud FL, Hernandez AJ, Mizobuchi RR, Laraya MH (2009) Measurement of tibial slope angle after medial opening wedge high tibial osteotomy: case series. *Sao Paulo Med J* 127(1):34–39
- Rodner CM, Adams DJ, Diaz-Doran V, Tate JP, Santangelo SA, Mazzocca AD, Arciero RA (2006) Medial opening wedge tibial osteotomy and the sagittal plane: the effect of increasing tibial slope on tibiofemoral contact pressure. *Am J Sports Med* 34:1431–1441
- Giffin JR, Vogrin TM, Zantop T, Woo SL, Harner CD (2004) Effects of increasing tibial slope on the biomechanics of the knee. *Am J Sports Med* 32(2):376–382
- Wright JM, Crockett HC, Slawski DP, Madsen MW, Windsor RE (2005) High tibial osteotomy. *J Am Acad Orthop Surg* 13:279–289
- Wright JM, Heavrin B, Begg M, Sakyrd G, Sterett W (2001) Observations on patellar height following opening wedge proximal tibial osteotomy. *Am J Knee Surg* 14:163–173
- Schröter S, Lobenhoffer P, Mueller J, Ihle C, Stöckle U, Albrecht D (2012) Changes of patella position after closed and open wedge high tibial osteotomy: review of the literature. *Orthopade* 41(3):186, 8–94
- Takeuchi R, Ishikawa H, Aratake M, Bito H, Saito I, Kumagai K, Akamatsu Y, Saito T (2009) Medial opening wedge high tibial osteotomy with early full weight bearing. *Arthroscopy. J Arthroscop Relat Surg* 25:46–53
- Turi G, Cassini M, Tomasi PS, Armotti P, Lavini F (1987) L'osteotomia direzionale di ginocchio mediante la "emicallotasi"-chir *Organi Nov*, 72, 205-9
- Nakamura E, Mizuta H, Kudo S, Takagi K, Sakamoto K (2001) Open-wedge osteotomy of the proximal tibia with hemicallotasis. *J Bone Joint Surg [Br]* 83(B):1111–1115
- Amendola A, Bonasia DE (2010) Results of high tibial osteotomy: review of the literature. *Int Orthop (SICOT)* 34:155–160
- Kolb W, Guhlmann H, Windisch C, Kolb K (2012) High tibial open-wedge osteotomy – New techniques and early results, osteoarthritis - diagnosis, treatment and surgery. In Tech Prof Qian Chen (Ed) doi: 10.5772/29838

24. Chesworth BM, Mahomed NN, Bourne RB, Davis AM et al (2008) Willingness to go through surgery again validated the WOMAC clinically important difference from THR/TKR surgery. *J Clin Epidemiol* 61(9):907–918
25. Gaasbeek RD, Nicolaas L, Rijnberg WJ, van Loon CJ, van Kampen A, Gaasbeek A (2010) Correction accuracy and collateral laxity in open versus closed wedge high tibial osteotomy. A one-year randomised controlled study. *Int Orthop (SICOT)* 34, 201–7
26. Ribeiro CH, Severino NR, Cury Rde P, de Oliveira VM, Avakian R, Ayhara T, de Camargo OP (2009) A new fixation material for open-wedge tibial osteotomy for genu varum-The. *Knee* 16(5):366–370
27. Kolb W, Guhlmann H, Windisch C, Kolb K, Koller H, Grützner P (2009) Opening-wedge high tibial osteotomy with a locked low-profile plate. *J Bone Joint Surg Am* 91:2581–2588
28. Shiha A, El-Deen MA, Khalifa AR, Kenawey M (2009) Ilizarov gradual correction of genu varum deformity in adults. *Acta Orthop Belg* 75:784–791
29. Magyar G, Ah TL, Vibe P, Toksvig-Larsen S, Lindstrand A (1999) Open-wedge osteotomy by hemicallotaxis or the closed-wedge technique for osteoarthritis of the knee. A randomised study of 50 operations *J Bone Joint Surg (Br)* 81, 444–8
30. Noyes FR, Goebel SX, West J (2005) Opening wedge tibial osteotomy: the 3-triangle method to correct axial alignment and tibial slope. *Am J Sports Med* 33:378–387
31. Marti CB, Gautier E, Wachtl SW, Jakob RP (2004) Accuracy of frontal and sagittal plane correction in open-wedge high tibial osteotomy (Review). *Arthroscopy. J Arthroscop Relat Surg* 20: 366–372
32. Lee SC, Jung KA, Nam CH, Jung SH, Hwang SH (2010) The short-term follow-up results of open wedge high tibial osteotomy with using an aescula open wedge plate and an allogenic bone graft: the minimum 1-year follow-up results. *Clin Orthop Surg* 2:47–54