Original Article

A retrospective analysis of medial opening wedge high tibial osteotomy for varus osteoarthritic knee

Chaturong Pornrattanamaneewong, Surin Numkanisorn, Keerati Chareancholvanich, Thossart Harnroongroj

Abstract

Background: Medial opening wedge high tibial osteotomy (MOWHTO) has proven to be an effective treatment for varus osteoarthritic knees. Various methods of fixation with different implant types and using either bone grafts or bone substitutes have been reported. We performed non-locking T-buttress plate fixation with autologous iliac bone graft augmentation, which is defined here as the traditional method, and locking compression plate fixation without any bone graft or bone substitute. We aimed to compare bone union and complications of these two MOWHTO techniques.

Materials and Methods: Between June 2005 and December 2007, 50 patients who underwent MOWHTO (a total of 60 knees) were retrospectively reviewed and classified into two groups: group A, which consisted of 26 patients (30 knees) was treated using T-buttress plate fixation with autologous iliac bone graft augmentation and group B, which consisted of 24 patients (30 knees) was operated upon using a medial high tibial locking compression plate without any augmentation. Demographic characteristics and radiographic outcomes, including union rate, time to union, medial osteotomy defects, and complications, were collected and compared between the two groups. The progress of all patients was followed for at least 2 years.

Results: All osteotomies united within 12 weeks after surgery. Group B had slightly longer time to union than group A (10.3 weeks and 9.5 weeks, respectively; $P = 0.125$). A significantly higher incidence of medial defects after osteotomy was reported in the locking compression plate group ($P = 0.001$). A total of 5 (8.3%) knees had complications. In group A, one knee had a superficial wound infection and another knee had a lateral tibial plateau fracture without significant loss of correction. In group B, one knee had screw penetration into the knee joint and two knees had local irritation that required the removal of the hardware.

Conclusion: Locking compression plate fixation without the use of bone grafts or bone substitutes provides a satisfactory union rate and an acceptable complication rate when compared to the traditional MOWHTO technique. Thus, we recommend using this technique for treating unicompartmental medial knee osteoarthritis.

Keywords: Medial, high tibial osteotomy, locking compression plate, T-buttress plate, bone graft

Introduction

High tibial osteotomy (HTO) was introduced by Jackson *et al.* in 1961[1] and popularized by Coventry in 1985.[2] It gained acceptance for correcting deformities and reducing pain in the treatment of unicondylar osteoarthritic knee. The principle of this procedure is to redistribute the weight-bearing load from the arthritic portion to the viable articular cartilage portion of the knee. The use of medial opening wedge high tibial osteotomy (MOWHTO) for the treatment of varus malaligned knees has increased because it offers improvements over the lateral closing wedge techniques, including the fact that it is easier to perform, corrects the deformity close to its origin, provides more predictable corrections and better preservation of the bone stock, and avoids injuries to the peroneal nerve and proximal tibiofibular joint.[3] However, many complications, such as nonunion, infection, penetrating osteotomy cuts or screws into the tibiofemoral joint, tibial plateau fracture, and the loss of correction angle, have been reported.[3-8]

MOWHTO surgical techniques have undergone many variations in fixation techniques and in the use of bone grafts or bone substitute augmentation.[7-16] In our institute, we use medial opening wedge techniques with two different methods of fixation. The first method involves the use of a T-buttress plate with autologous tricortical iliac bone

Department of Orthopedic surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

Address for correspondence: Prof. Thossart Harnroongroj, MD.
Department of Orthopedic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand
E-mail: tkt108@yahoo.co.th

Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.98833

graft augmentation.[17,18] With this method, a potential concern is the possibility of donor site morbidities, which can include chronic pain, infections, and paresthesia.[19] To avoid these complications, a second method, which uses a locking compression plate (LCP) without any bone grafts or bone substitutes, has been performed. This study aims to compare the results of these two methods.

Materials and Methods

We retrospectively reviewed the medical records and radiographs of the patients who underwent MOWHTO at our institute between June 2005 and December 2007. Fifty five patients (65 knees) with primary medial unicompartmental knee osteoarthritis were included. The preoperative exclusion criteria were symptomatic osteoarthritis in the lateral or patellofemoral compartments, osteoporosis (defined as a bone mineral density that lies 2.5 standard deviations more below the average value for young healthy women), varus deformity >15°, flexion contracture >10°, range of motion <90°, and the presence of severe osteoarthritis (defined as a grade of 4 on the Kellgren–Lawrence radiographic grading scale[20]). Five patients for whom data for the entire 2-year followup period were not available were excluded. Therefore, a total of 60 knees from 50 patients were included in our study. This study was approved by the ethics committee of our hospital.

Based on the surgical fixation methods used in each patient, the subjects were classified into two groups. Group A consisted of 30 osteotomies (26 patients) using T-buttress plates (for 4.5 mm screws) with autologous tricortical iliac bone graft augmentation [Figure 1]. The other 30 osteotomies (24 patients) used TomoFix plates (AO locking compression medial high tibial plate and Ti/4H 4.5–5.0 mm, Synthes, Bettlach, Switzerland) without bone grafts or bone substitutes and were classified as group B [Figure 2]. Clinical and radiologic outcomes of the two groups were obtained and compared. All patients were followed up postoperatively at 4, 8, 12, and 16 weeks, and after 6 months, 1 year, and 2 years.

Operative procedure

In group A, all osteotomies were performed by senior author (TH), and in group B, all osteotomies were performed by another senior author (KC). Other than fixation, all procedures were performed in the same manner without arthroscopy. Preoperative planning and postoperative analyses were based on preoperative and postoperative (4-week) digitalized standing hip-to-ankle radiographs, respectively. All radiographs had the patella facing directly anterior. The weight-bearing line was planned and calculated to pass Fujisawa's point (at 30–40% lateral

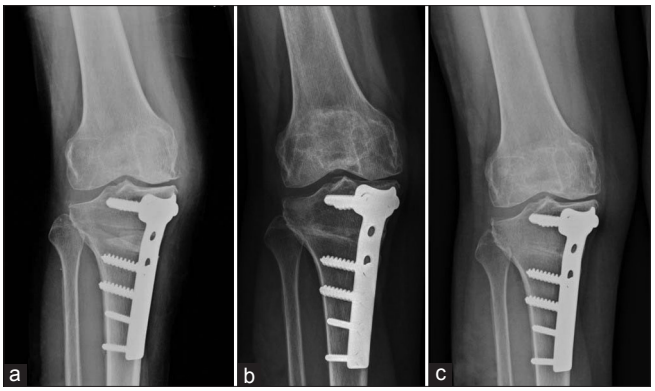

Figure 1: Postoperative radiographs (anteroposterior view) after medial opening wedge high tibial osteotomy using T-buttress plates with autologous iliac bone graft augmentation at (a) 2 weeks, (b) 12 weeks, and (c) 2 years showing medial placement of the bone graft as possible can reduce the incidence of medial defect

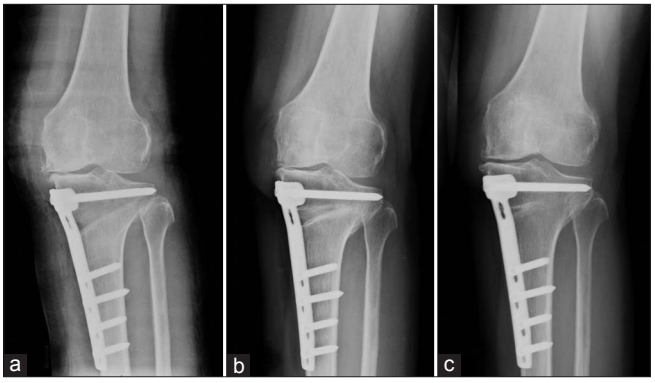

Figure 2: Postoperative radiographs (anteroposterior view) after medial opening wedge high tibial osteotomy using TomoFix plates without any augmentation at (a) 2 weeks, (b) 12 weeks, and (c) 2 years showing progressive healing from lateral to medial side and medial defect

to the midpoint of the tibial plateau).[21] Each patient was positioned in a supine position on a radiolucent table with a thigh tourniquet. An oblique incision was made from a point just distal to the medial joint line to the level of the tibial tubercle. The superficial medial collateral ligament was subperiosteally released from the proximal tibia and its complete release was confirmed using a valgus stress test under fluoroscopic examination. A Kirschner wire was inserted in the oblique direction from the metaphyseal–diaphyseal junction of the medial proximal tibial cortex, which corresponds to a point just above the upper border of the pes anserinus, and was directed toward the lateral proximal tibial cortex at the level of the tip of the fibular head. Osteotomies were performed beneath the wire using an osteotome and an oscillating saw while the knee was in a 15° flexed position. An ascending cut was made behind the tibial tuberosity in the anterior fourth or 1.5 cm posterior to the anterior rim of the tibial tuberosity, leaving the patellar ligament attached to the distal tibial fragment. Osteotomies ended 5 mm medial to the lateral cortex. Osteotomies were opened gradually using two flat chisels, and the gaps were

maintained with a spreader. The intraoperative mechanical axis was controlled using the cable technique[22] with a rigid bar holding the knee in a fully extended position. For group A patients, a triangular tricortical iliac bone graft was harvested from the ipsilateral iliac crest, fashioned into the appropriate size and shape, impacted into the osteotomy site, and fixed in place using a T-buttress plate. Internal fixation was achieved in group B patients using a TomoFix plate without bone grafts. A 10-gauge drain was placed over the plate. After wound closure, a compressive Robert Jones bandage was applied.

Isometric quadriceps exercises, active ankle pumping and straight leg-raising exercises were started on the first postoperative day. The drain and compressive dressing were removed on the second day after surgery. Each patient was allowed to move the knee as much as tolerated and walk with toe-touch weight bearing for the first 2 weeks after surgery. Partial weight bearing was permitted for the next 2 weeks, and full weight bearing was permitted beginning 4 weeks after the operation.

The degree of osteoarthritis was assessed preoperatively using the Kellgren–Lawrence radiographic grading scale. The picture archiving and communications system (PACS) measurement tools were used for determining the following radiographic values: 1) the preoperative and postoperative medial joint space, which are defined as the narrowest width of joint space in the medial tibiofemoral compartment as observed from the anteroposterior view of the knee, 2) the preoperative femorotibial varus angle [Figure 3] and the postoperative femorotibial valgus angle, 3) the correction angle (e.g., the difference between the preoperative and postoperative femorotibial angles), and 4) the medial defect of the osteotomy, which is defined as the length of the defect that is at least 5 mm wide from the lateral edge of the defect to the lateral plate border in perpendicular with the tibial axis [Figure 4].

The time required for bone union was evaluated according to Apley and Solomon's criteria.[23] These criteria define complete bone union as the time at which there is an absence of pain upon local palpation, an absence of swelling in the limb, an ability to walk painlessly without crutches, and an evidence of a radiographic bridging callus or trabecula between fragments. Radiographic assessments were conducted separately by each of the two orthopedists at every followup visit until both agreed that the osteotomy was united. Delayed unions were defined as unions occurring after 12 weeks, and nonunions were diagnosed when trabecular discontinuity was still observed 6 months after surgery. However, after the 4-week followup, some osteotomies yielded only standing knee films. Thus, we could not measure the femorotibial angle, which would have been required to determine whether there was a loss of the correction angle.

The data were analyzed using SPSS version 13.0. Chi-square tests, *t*-tests, or Mann–Whitney U-tests were performed to evaluate the significance of group differences. Fisher's exact test was used to determine

Figure 3: X-ray anteroposterior view including hip, knee and ankle joint in a single plate showing preoperative femorotibial varus angle drawn between anatomical axis of the femur and tibia, sample from group A (left image, 4°) and group B (right image, 5°)

Figure 4: X-ray knee joint with proximal tibia showing measurements of medial osteotomy defects (x)

the non-random associations between two categorical variables. *P*-values less than 0.05 were considered to be statistically significant.

Results

There were no significant differences in demographic characteristics between the two groups except that patients in group B were slightly younger than those in group A. Overall, complications were reported in 5 (8.3%) out of 60 knees. In group A, one knee had a superficial wound infection, which was successfully treated with intravenous antibiotics and local wound care. Another patient suffered a lateral tibial plateau fracture in the knee after a postoperative fall, but the correction angle was maintained. We successfully treated the patient in cast. In group B, one knee exhibited screw penetration into the posterolateral portion of the knee joint, but this did not cause any symptoms. The other two knees in which complications were reported exhibited local irritation that required the removal of hardware 2 years after surgery. No deep wound infections, vascular injuries, or incidents of clinically detected deep vein thrombosis were reported in either group. In addition, there were no reports of serious donor site complications, such as iliac bone fracture, major hematoma, or nerve injury, at the iliac bone graft harvest site. However, the harvest site was a source of pain for patients during the first postoperative 6 months, an effect that prolonged patient recovery time. No patient required revision of fixation or subsequent total knee arthroplasty.

We performed MOWHTO for cases of grade II or III unicompartmental osteoarthritis of the knee that still had medial joint space. There were no significant differences between groups with respect to the preoperative femorotibial varus angle, the postoperative femorotibial valgus angle, or the correction angle. MOWHTO resulted in bone union in all patients within 8–12 weeks and time to union was similar in both groups ($P = 0.125$). No delayed unions or nonunions were detected in our subjects.

Nevertheless, 1 year following surgery, a significantly higher percentage of osteotomies with medial defects was found in TomoFix group ($P = 0.001$) and all defects remained until the time of the 2-year followup appointment. In addition, subgroup analysis revealed that 10 (33.3%) knees in group A had medial defects at the time of osteotomy. Measurements of the distance between the lateral border of the T-buttress plate and the medial border of bone graft in these cases revealed that the bone grafts were placed 8.0 ± 1.9 mm (range 6–12 mm) away from the plate. These defects were still observed 2 years following surgery. In contrast, in group A osteotomies that did not exhibit medial defects, all bone grafts were placed within 5 mm of the plate. In group B, 80% of osteotomies fixed with TomoFix had medial defects and we did not find any correlating factors with these defects in this study.

Discussion

HTO is a widely accepted procedure for treating medial knee osteoarthritis. It not only improves knee function but also allows for the healing of articular cartilage.[24] Although a recent meta-analysis revealed no significant differences in complication incidence, including incidence of infection, deep vein thrombosis, peroneal nerve palsy, nonunion, or revision to knee arthroplasty between MOWHTO and lateral closing wedge HTO,[25] MOWHTO still has several advantages over lateral closing wedge HTO and has gained popularity at our institute and elsewhere in recent years.[3,7,11,12,26]

Although Trieb *et al.*[27] reported that the older patients (≥65 years) had a significantly higher risk for failure of HTO, they used the lateral closing wedge technique. In spite of the age difference between our groups, no failure of osteotomies was observed in this series. Previous studies have reported the complication rate after MOWHTO to be between 1.9% and 55%.[6,7,10,11,26,28-31] Depending on the type of implants, the use of Puddu plates has been reported to be associated with a high complication rate (37.7–55%),[26,28-29] whereas using LCP and non-locking T-plates has been associated with a much lower complication rate (1.9–8.6%).[7,30,31] In comparison, the current study was characterized by a low complication rate with both the use of T-buttress plates (6.7%) and the TomoFix technique (10%). However, the loss of correction could not be recorded due to the lack of the full-length films during the followup period.

Furthermore, complications related to the implant itself occurred only in the group using TomoFix. Because of inappropriate precontouring with our patients' anatomy and the irreversibility of the direction of locking screws, one case resulted in a screw penetrating into the knee joint. Thus, we suggest bending the TomoFix before hand to correct this problem in some patients. In the other two instances of implant complications, hardware removal was required because of the local irritation associated with the TomoFix implant.

To achieve the satisfactory outcomes after MOWHTO, there are both mechanical and biological factors that must be considered. Important mechanical factors include the fixation technique and having an intact lateral cortex and lateral soft-tissue hinge.[32,33] Although anatomical non-locking T-plates showed significantly better stability

than wedge-supported plates in a previous biomechanical study,[34] stronger fixation and increased stability may be required in human beings. However, relatively few studies have examined the use of this type of plate in clinical applications.[31] Furthermore, the use of bone grafts to fill gaps can increase mechanical stability and enhance bone healing.[12] Thus, in the non-locking T-buttress group, iliac bone grafting was required to provide adequate stability of the construct to allow the patients to engage in early mobilization. Nevertheless, persistent pain at the iliac crest and other donor site morbidities should be considered.[29] Although all of the patients in group A initially reported donor site pain, it disappeared spontaneously within 6 months.

In the other type of fixation, the fixed-angle device (TomoFix) provides adequate strength and a clear advantage, especially in obese patients, for osteotomies with large correction angles and for unstable osteotomies following lateral tibial cortex fractures.[35,36] Thus, several studies have recommended using this fixation technique without interposition materials.[12,35-38]

Although autologous iliac bone grafts are considered to be the gold standard,[8,39,40] donor site morbidity with these grafts is unavoidable. The use of synthetic bone substitutes is another option, but this technique has also been reported to have several disadvantages, including delayed incorporation into bone, soft tissue irritation, and infections.[41,42] When using TomoFix alone, the elasticity of the plate has been shown to be an essential factor in encouraging bone growth by mechanical stimulation,[43] even without bone grafts or the use of bone substitute material. Our results here indicate that the TomoFix technique provides similar union rates as the traditional technique.

Although radiological evaluations of the stage of union are correct in only approximately 50% even in tibial shaft fractures,[44] their use remains vital in clinical practice. To increase the reliability of these examinations, we evaluated both the clinical and the radiographic union using separate assessments. Unlike a previous study by Meidinger *et al.*,[45] we found that all osteotomies in our series became united within 8–12 weeks, regardless of patient demographics, including age, smoking status, or body weight. However, patients in the TomoFix group required a nonsignificantly longer time to form bone unions than patievnts treated with the traditional method.

One significant radiographic outcome of this study was a difference in medial defects between the two groups. For the purposes of this study, medial defects were arbitrarily defined as defects >5 mm in width. This definition was based on a previous study by Completo *et al.*[46] that examined strain changes and notch depths of the anterior femoral cortex. They reported that notch depths greater than 5 mm (full-thickness cortical defect) led to significant strain increases at the notch edge, weakening of the femoral cortex, and increased risk of femoral fractures. Thus, we are concerned that a remaining medial defect of >5 mm after union might increase the risk of proximal tibial fracture when the patients need to take the hardware out.

However, in patients treated with a T-buttress plate and a bone graft, 33.3% of medial defects were related to placing the bone graft laterally too far from the medial cortex. Therefore, we recommend appropriate sizing and placement of the bone graft on the medial cortex to ensure cortical-to-cortical bone contact and reduce the incidence of medial defects [Figure 1]. In the other group, the healing progressed medially from the lateral hinge point, preserving the medial gap [Figure 2]. Thus, the incidence of medial defects was significantly higher in the TomoFix group (80%) than in patients treated using the traditional technique ($P = 0.001$). This effect is due to a stress-shielding effect that derives from the use of excessively rigid constructs.[47] The remaining medial defect may change the loading pattern on the proximal tibia and increase a risk of fracture. Further studies on these sequelae are required.

Conclusion

When combined with the use of a LCP without bone grafts or bone substitute, MOWHTO has been shown to provide satisfactory union rates and acceptable complication rates when compared to traditional techniques. However, achieving successful outcomes requires proper patient selection, effective planning, meticulous surgical techniques with some modifications, and good rehabilitative programs.

References

1. Jackson JP, Waugh W. Tibial osteotomy for osteoarthritis of the knee. J Bone Joint Surg Br 1961;43:746-51.
2. Coventry MB. Upper tibial osteotomy for osteoarthritis. J Bone Joint Surg Am. 1985;67:1136-40.
3. Dong JC, Gautam MS, Kook HW, Antonio Santa CM Jr, Jong IK, Kyung WN. Early complications of medial opening wedge high tibial osteotomy using autologous tricortical iliac bone graft and T-plate fixation. Knee 2011;18:278-84.
4. Valkering KP, van den Bekerom MP, Kappelhoff FM, Albers GH. Complications after tomofix medial opening wedge high tibial osteotomy. J Knee Surg 2009;22:218-25.
5. Matthews LS, Goldstein SA, Malvitz TA, Katz BP, Kaufer H. Proximal tibial osteotomy. Factors that influence the duration of satisfactory function. Clin Orthop 1988;229:193-200.

6. Miller BS, Downie B, McDonough EB, Wojtys EM. Complications after medial opening wedge high tibial osteotomy. Arthroscopy 2009;25:639-46.
7. Niemeyer P, Schmal H, Hauschild O, von Heyden J, Südkamp NP, Köstler W. Open-wedge osteotomy using an internal plate fixator in patients with medial-compartment gonarthritis and varus malalignment: 3-year results with regard to preoperative arthroscopic and radiographic findings. Arthroscopy 2010;26:1607-16.
8. Warden SJ, Morris HG, Crossley KM, Brukner PD, Bennell KL. Delayed- and nonunion following opening wedge high tibial osteotomy: surgeons' results from 182 completed cases. Knee Surg Sports Traumatol Arthrosc 2005;13:34-7.
9. Agneskirchner JD, Freiling D, Hurschler C, Lobenhoffer P. Primary stability of four different implants for opening wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2006;14:291-300.
10. Amendola A, Fowler PJ, Litchfield R, Kirkley S, Clatworthy M. Opening wedge high tibial osteotomy using a novel technique: early results and complications. J Knee Surg 2004;17:164-9.
11. Asik M, Sen C, Kilic B, Goksan SB, Ciftci F, Taser OF. High tibial osteotomy with Puddu plate for the treatment of varus gonarthrosis. Knee Surg Sports Traumatol Arthrosc. 2006;14:948-54.
12. Brinkman JM, Lobenhoffer P, Agneskirchner JD, Staubli AE, Wymenga AB, van Heerwaarden RJ. Osteotomies around the knee: patient selection, stability of fixation and bone healing in high tibial osteotomies. J Bone Joint Surg Br 2008;90-B:1548-57.
13. Chae DJ, Shetty GM, Lee DB, Choi HW, Han SB, Nha KW. Tibial slope and patellar height after opening wedge high tibia osteotomy using autologous tricortical iliac bone graft. Knee 2008;15:128-33.
14. De Simoni C, Staubli A. Neue Fixationstechniken fur mediale open-wedge Osteotomien der proximalen Tibia. Schweiz Med Wochenschr 2000;119:130.
15. Koshino T, Murase T, Saito T. Medial opening-wedge high tibial osteotomy with use of porous hydroxyapatite to treat medial compartment osteoarthritis of the knee. J Bone Joint Surg Am 2003;85:78-85.
16. Noyes FR, Mayfield W, Barber-Westin SD, Albright JC, Heckmann TP. Opening wedge high tibial osteotomy: an operative technique and rehabilitation program to decrease complications and promote early union and function. Am J Sports Med 2006;34:1262-73.
17. Harnroongroj T, Vanadurongwan V. The stable upper tibial osteotomy for the treatment of osteoarthritic knee: Medial opening step wedge technique (Part II). Siriraj Hosp Gaz 1994;46:28-33.
18. Harnroongroj T, Vanadurongwan V. The stable upper tibial osteotomy for the treatment of osteoarthritic knee: The simplified medial opening step wedge technique (Part III). Siriraj Hosp Gaz 1994;46:120-5.
19. Younger EM, Chapman MW. Morbidity at bone graft donor sites. J Orthop Trauma 1989;3:192-5.
20. Kellgren JH, Jeffrey M, Ball J. Atlas of standard radiographs. Vol 2. Oxford: Blackwell Scientific, 1963.
21. Fujisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee. Orthop Clin North Am. 1970;10:585-608.
22. Krettek C, Miclau T, Grun O. Intraoperative control of axes, rotation and length in femoral and tibial fractures. Technical note. Injury 1998;29:29-39.
23. Apley AG, Solomon L. Apleys system of orthopaedics and fractures. 7th edn. United Kingdom: Butterworth and Heinemann; 1994
24. Koshino T, Wada S, Ara Y, Saito T. Regeneration of degenerated articular cartilage after high tibial valgus osteotomy for medial compartmental osteoarthritis of the knee. Knee. 2003;10: 229-36.
25. Smith TO, Sexton D, Mitchell P, Hing CB. Opening- or closing-wedged high tibial osteotomy: A meta-analysis of clinical and radiological outcomes. Knee. 2010;18:361-8.
26. van den Bekerom MP, Patt TW, Kleinhout MY, van der Vis HM, Albers GH. Early complications after high tibial osteotomy: a comparison of two techniques. J Knee Surg 2008;21:68-74.
27. Trieb K, Grohs J, Hanslik-Schnabel B, Stulnig T, Panotopoulos J, Wanivenhaus A. Age predicts outcome of high-tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2006;14:149-52.
28. Esenkaya I, Elmali N. Proximal tibia medial open-wedge osteotomy using plates with wedges: early results in 58 cases. Knee Surg Sports Traumatol Arthrosc 2006;14:955-61.
29. Brouwer RW, Bierma-Zeinstra SM, van Raaij TM, Verhaar JA. Osteotomy for medial compartment arthritis of the knee using a closing wedge or an opening wedge controlled by a Puddu plate. A one-year randomised, controlled study. J Bone Joint Surg Br 2006;88:1454-9.
30. Kolb W, Guhlmann H, Windisch C, Kolb K, Koller H, Grützner P. Opening-wedge high tibial osteotomy with a locked low-profile plate. J Bone Joint Surg Am 2009;91:2581-8.
31. Santic V, Tudor A, Sestan B, Legovic D, Sirola L, Rakovac I. Bone allograft provides bone healing in the medial opening high tibial osteotomy. Int Orthop 2010;34:225-9.
32. Coventry MB, Ilstrup DM, Wallrichs SL. Proximal tibial osteotomy. A critical longterm study of eighty-seven cases. J Bone Joint Surg Am 1993;75:196-201.
33. Rose T, Imhoff AB. Complications after transgenicular osteotomies. Oper Tech Orthop 2007;17:80-6.
34. Esenkayaa I, Misirlioglua M, Kelestemurb MH, Elmalia N, Fadillioglu E. Biomechanical evaluation of different fixation plates in medial opening upper tibial osteotomy. Knee 2007;14:46-50.
35. Lobenhoffer P, De Simoni C, Staubli AE. Open-wedge high-tibial osteotomy with rigid plate fixation. Tech Knee Surg 2002;1: 93-105.
36. Stoffel K, Stachowiak G, Kuster M. Open wedge high tibial osteotomy: biomechanical investigation of the modified Arthrex Osteotomy Plate (Puddu Plate) and the TomoFix Plate. Clin Biomech 2004;19:944-50.
37. El-Assal MA, Khalifa YE, Abdel-Hamid MM, Said HG, Bakr Hatem MA. Opening-wedge high tibial osteotomy without bone graft. Knee Surg Sports Traumatol Arthrosc 2010;18:961-6.
38. Staubli AE, Jacob HA. Evolution of open-wedge high-tibial osteotomy: experience with a special angular stable device for internal fixation without interposition material. Int Orthop 2010;34:167-72.
39. Franco V, Cerullo G, Cipolla M, Gianni E, Puddu G. Open wedge high tibial osteotomy. Tech Knee Surg 2002;1:43-53.
40. Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy for osteoarthritis with varus deformity: a ten to thirteen-year follow-up study. J Bone Joint Surg Am 1987;69:332-54.
41. Spahn G. Complications in high tibial (medial opening wedge) osteotomy. Arch Orthop Trauma Surg 2004;124:649-53.
42. van Hemert WL, Willems K, Anderson PG, van Heerwaarden RJ,

Wymenga AB. Tricalcium phosphate granules or rigid wedge preforms in open wedge high tibial osteotomy: A radiological study with a new evaluation system. Knee 2004;11:451-6.
43. Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a balance between stability and biology. J Bone Joint Surg Br 2002;84:1093-110.
44. Hammer R, Hammerby S, Lindholm B. Accuracy of radiological assessment of tibial shaft fractures in humans. Clin Orthop 1985;199:233-8.
45. Meidinger G, Imhoff AB, Paul J, Kirchhoff C, Sauerschnig M, Hinterwimmer S. May smokers and overweight patients be treated with a medial open-wedge HTO? Risk factors for nonunion. Knee Surg Sports Traumatol Arthrosc 2011;19: 333-9.
46. Completo A, Fonseca F, Relvas C, Ramos A, Simões JA. Improved stability with intramedullary stem after anterior femoral notching in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2011;20:487-94.
47. Bottlang M, Doornink J, Lujan TJ, Fitzpatrick DC, Marsh JL, Augat P, *et al*. Effects of construct stiffness on healing of fractures stabilized with locking plates. J Bone Joint Surg Am 2010;92 Suppl 2:12-22.

How to cite this article: Pornrattanamaneewong C, Numkanisorn S, Chareancholvanich K, Harnroongroj T. A retrospective analysis of medial opening wedge high tibial osteotomy for varus osteoarthritic knee. Indian J Orthop 2012;46:455-61.

Source of Support: Nil, **Conflict of Interest:** The authors wish to state that no funds or benefits from any source were received by any of the authors in support of this study/article.