Loss of Correction after Medial Opening Wedge High Tibial Osteotomy: A Comparison of Locking Plates without Bone Grafts and Non-Locking Compression Plates with Bone Grafts

Chaturong Pornrattanamaneewong MD*,
Thossart Harnroongroj MD*, Keerati Chareancholvanich MD*

** Department of Orthopeadic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Background: *A loss of correction is one of the common complications after medial opening wedge high tibial osteotomy (MOWHTO) and can lead to deteriorate outcomes. The technique of fixation plays an important role in maintaining the correction angle until union.*
Objective: *The present study aims to compare the amount of correction loss between two different fixation techniques after MOWHTO.*
Material and Method: *Between 2005 and 2007, 67 knees from 54 patients who underwent MOWHTO were reviewed and classified into the following groups: group A, treated with T-buttress plate fixation and autologous tricortical iliac bone graft, and group B, operated upon with a locking compression medial high tibial plate without any augmentation. Preoperatively and at 1, 12 and 24 months postoperatively, medial proximal tibial angles (MPTA) were measured and the loss of correction angle was determined by measuring the decrease in MPTAs at 1 and 2 years after the operation. The differences in clinical and radiographic outcomes were analyzed using Student's t-test and the Chi-squared test.*
Results: *The overall loss of correction at 2 years in group A (2.0 $\pm$ 2.7 degrees) was higher than in group B (0.3 $\pm$ 3.3 degree) (p = 0.026). The majority of correction loss occurred in the first year (1.6 $\pm$ 2.6 and 0.4 $\pm$ 2.6 degrees in groups A and B, respectively). During the second year, there was slightly more loss in group A (0.4 $\pm$ 1.3 degree), while a stable angle was found in group B (-0.1 $\pm$ 2.5 degree). All osteotomies were united and a 7.5% incidence of overall complications was reported.*
Conclusion: *Maintenance of the correction angle after MOWHTO depended on the fixation technique. The authors recommend that 2 degrees more than the planned overcorrection point is required in the non-locking plate system, with no need for such a measure in the locking plate system.*

Keywords: *Loss of correction, High tibial osteotomy, Locking compression plate, Medial tibial plateau angle*

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Medial opening wedge high tibial osteotomy (MOWHTO) is an effective treatment for symptomatic varus malaligned knees[1-4]. It has been claimed that there are several advantages over the lateral closing wedge technique, including easier technique, correction of the deformity close to its origin, more predictable correction, the preservation of bone stock and the avoidance of peroneal nerve and proximal tibiofibular joint injury[5,6]. The pain improvement and the long-term outcome of this operation depend on the accuracy of correction and correction angle after the osteotomy has united[3,7].

Correspondence to:
Chareancholvanich K, Department of Orthopeadic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 0-2419-7968, Fax: 0-2412-8172
E-mail: sikcr@mahidol.ac.th

Loss of correction is one of the common complications after osteotomy and can lead to recurrent varus deformity, the progression of medial joint arthritis and patient dissatisfaction[3,8,9]. Stability of the constructions, including type of fixation with or without the use of bone grafts or bone substitutes, are the most important factors for maintaining the correction angle until osteotomy healing. The aim of the present study was to compare the amount of correction angle loss between two different fixation techniques after MOWHTO.

Material and Method

Study population

Between 2005 and 2008, 75 knees (from 60 patients) that underwent MOWHTOs at our institute were retrospectively reviewed. Eight knees (from 6 patients) that did not match our radiographic criteria were excluded. Therefore, the results were evaluated in 67 knees from 54 patients. These subjects could be classified into two groups depending on the fixation techniques.

Thirty MOWHTOS (from 26 patients) operated upon with T-buttress plate (for 4.5-mm screws) fixation and autologous tricortical iliac bone graft insertion was classified as group A (Fig. 1). Group B consisted of 37 osteotomies (28 patients) operated upon with the Tomofix™ plate (AO locking compression medial high tibial plate and Ti/4H 4.5-5.0 mm, Synthes, Switzerland) fixation without any augmentation (Fig. 2). All patients were followed-up at 4, 8, 12 and 16 weeks, 6 months and 1 and 2 years postoperatively. Clinical and radiographic outcomes were compared.

Fig. 1 The radiographs show the medial opening wedge high tibial osteotomy using T-buttress plate with autologous tricortical iliac bone graft

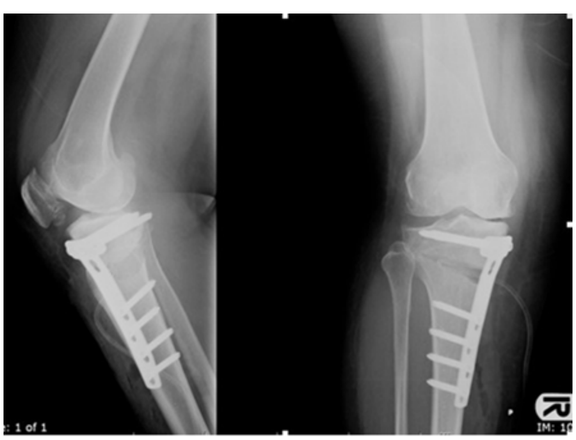

Fig. 2 The radiographs show the medial opening wedge high tibial osteotomy using Tomofix plate without bone graft

Operative technique

The MOWHTO surgical technique was first developed and reported at our institute in 1994[10,11]. All osteotomies in group A and B were performed by our senior authors (TH and KC, respectively). Preoperative planning and postoperative analysis were based on the digitalized standing hip-to-ankle radiographs. The weight-bearing line was designed to pass Fujisawa's point[12]. The procedure was performed via an oblique skin incision. After the superficial medial collateral ligament was subperiosteally released from the proximal tibia, a Kirschner wire was inserted in the oblique direction from the metaphyso-diaphyseal junction of the medial proximal tibial cortex and extended to the lateral proximal tibial cortex at the level of the tip of the fibular head. The osteotomy was created beneath the wire. In the anterior fourth of the tibial tuberosity, an ascending cut was created behind the tibial tuberosity, leaving the patellar ligament attached to the distal tibial fragment. The osteotomy ended 5 mm medial to the lateral cortex. The osteotomy was opened gradually using two flat chisels and the gap was maintained with a spreader. The intraoperative mechanical axis was controlled by the cable method[13]. Internal fixation was performed using a T-buttress plate with an ipsilateral iliac bone graft in group A and using the Tomofix™ plate without any augmentation in group B.

The isometric quadriceps exercise, active ankle pumping and straight leg raising were started on the first postoperative day. The drain and compressive dressing were removed on the second day after surgery. The patient was allowed to move the knee as tolerated and walk with toe-touch weight-bearing for 2 weeks followed by partial weight bearing for the next 2 weeks. Full weight bearing was permitted at 4 weeks after the operation. Postoperative radiographs were evaluated at 1 month, 1 year and 2 years.

Radiographic measurement

The picture archiving and communication system (PACS) measurement tools were used for radiographic value measurement. Medial proximal tibial angle (MPTA) as described by Paley D[14]. was the referenced angle in determining the deformity correction angle. MPTA was the medial angle between two lines: one line of the tibial anatomical axis and a second line from the medial- to lateral-most of the tibial plateaus excluding osteophytes (line of the tibial plateau surface) (Fig. 3). The advantage of this angle was that it directly represented the true correction angle of the osteotomy without any effect of the status of the knee's collateral ligament. The authors evaluated the MPTA preoperatively and postoperatively at 1 month, 1 year and 2 years. Loss of the correction angle was determined by decreasing the role of MPTA at 1 and 2 years after the operation.

In addition, the other radiographic outcomes recorded in the present study were: (1) the degree of knee osteoarthritis classified by the Kellgren-Lawrence radiographic grading scale, (2) the femorotibial angle (FTA), which was the angle formed by the mechanical axis of the femur (from the center of the femoral head to the top of the femoral notch) and the tibia (from the center of the ankle to the center of the tibial spines) (Fig. 3), and (3) union of the osteotomy, which was evaluated according to Apley and Solomon's criteria[15] by two orthopeadists blinded to treatment group. 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 without pain without crutches and evidence of a radiographic bridging callus or trabecula between fragments at 1 year postoperatively.

Setting the radiographic criteria, we studied the effect of lower extremity rotation on MPTA value by assessing 10 radiographs after MOWHTOs. Each film was obtained in neutral, 15° external rotation and 15° internal rotation views of the knee. The authord found that, in the internal rotation view, the patellar center moved into the medial two-fifths of the distal femur and MPTA increased by 4.7 $\pm$ 1.2°. However, MPTA decreased by 6.5 $\pm$ 1.0° and the patella was positioned at the lateral two-fifths when the legs were externally rotated. Therefore, the anteroposterior views of the standing long films with the patellas centered (middle one-fifth) over the femoral condyles were selected as our criteria.

However, at 1 and 2 years of follow-up, fourteen osteotomies (6 in group A and 8 in group B) yielded standing short films with proximal tibial length of at least 15 cm. Unfortunately, the short films were unable to measure the FTA and made it difficult to identify the precise tibial anatomical axis for MPTA measurement. To verify the 15-cm proximal tibial length films with respect to the accuracy of MPTA measurement, we studied 20 standing hip-to-ankle radiographs after MOWHTOs. Each film was cropped and used to create a 30-cm-length short film of the knees (standard length of a short knee radiograph) with two different proximal tibia lengths: 10 and 15 cm (Fig. 4). MPTA was measured by two blinded orthopeadists. The deviation of MPTA was 0.5 $\pm$ 0.5° (range 0-1°) and 2.0 $\pm$ 1.0° (range 0-3°) in 15- and 10-cm proximal tibial length films, respectively, compared to the gold standard standing long films. Therefore, the additional criterion for standing short knee radiograph selection was that proximal tibial length of the film had to be at least 15 cm. Using these criteria, four imprecise long films in rotation and four inadequate-length short films were excluded from the present study.

Statistical analysis

The data were analyzed using the commercially available SPSS statistics software, version 13.0. Quantitative data were presented as the mean $\pm$ SD. The differences in quantitative and qualitative data were analyzed using Student's t-test and the Chi-squared test, respectively. With respect to the age

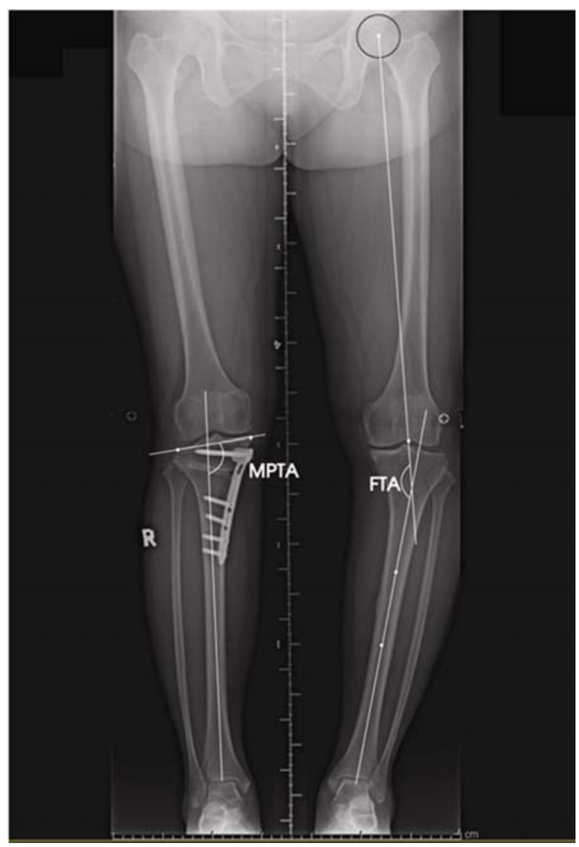

Fig. 3 The measurement of medial proximal tibial angle (MPTA) and femorotibial angle (FTA)

all film lengths.

Discussion

Loss of correction is one of the major complications after MOWHTO[16]. The incidence of this complication varies from 1.7 to 15.2%[2,16-19]. This rate depends on the definition of correction loss and

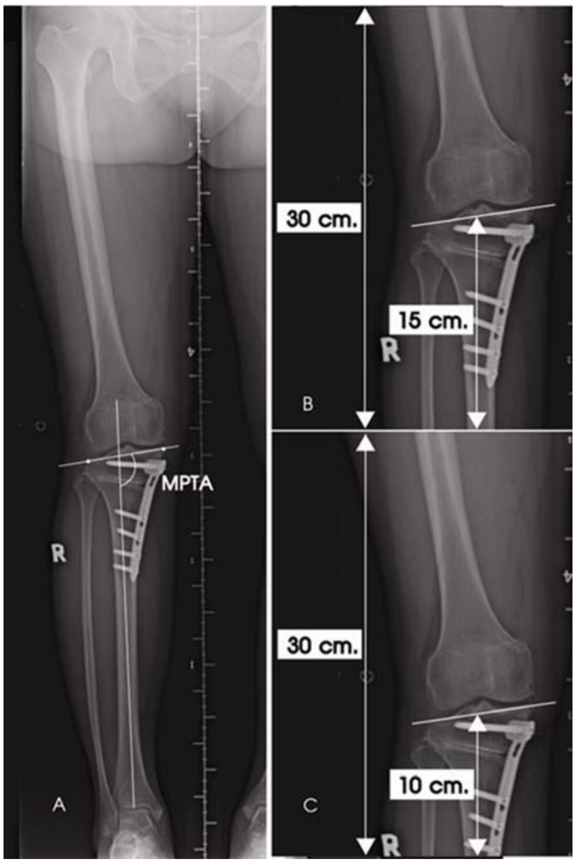

Fig. 4 The digitalized standing hip-to-ankle radiograph (A) was cropped and used to create 30-cm short films of the knees with two different proximal tibia lengths: 15 (B) and 10 cm (C)

difference between the two groups, the authors analyzed the loss of correction angle, adjusted for age, with analysis of covariance (ANCOVA). Pearson correlation coefficient was used to determine the correlation between the loss of correction angle and the subjects' demographics. P-values less than 0.05 were regarded as statistically significant. The intra- and inter-observer reproducibility of MPTA measurement was expressed as intraclass correlation coefficients (ICCs) that vary from zero (no agreement at all) to 1 (total agreement).

Results

The patients' characteristics of the two groups are shown in Table 1. Group B had a lower mean age (53.8 $\pm$ 4.8) than group A (63.4 $\pm$ 6.1) ($p < 0.001$) because one of the surgeons (KC) preferred to perform MOWHTO in patients who were not more than 60 years old.

For the radiologic results, there were no significant differences between the groups with respect to the degree of osteoarthritis, pre- and post-operative FTA, correction angle and preoperative MPTA (Table 2). Although significant differences were not reported in postoperative MPTA, the overall loss of correction after 2 years of treatment with the T-buttress plate in combination with bone graft (2.0 $\pm$ 2.7°) was higher than in the Tomofix™ group (0.3 $\pm$ 3.3°) ($p = 0.026$). The majority of correction angle loss occurred in the first year (1.6 $\pm$ 2.6°, range -2 to 7° and 0.4 $\pm$ 2.6°, range -9 to 4° in groups A and B, respectively). During the second year, there was slightly more loss in group A (0.4 $\pm$ 1.3°, range -2 to 3°), while a stable angle was found in group B (-0.1 $\pm$ 2.5°, range -6 to 7°) (Table 3). With respect to the difference in age between the groups, we analyzed the loss of correction, adjusted for age, with ANCOVA. The overall loss of correction still differed significantly ($p = 0.010$); a more significant difference was found in correction loss during the first year postoperatively (p

Table 1. Patients' characteristics of the two groups

Characteristics	Group A (n = 30)	Group B (n = 37)	p-value
Age (yrs)*	63.4 $\pm$ 6.1	53.8 $\pm$ 4.8	< 0.001
Sex (Female:Male)	24:6	34:3	0.279
Side (Right:Left)	21:9	15:22	0.031
BMI (kg/m^2)*	27.1 $\pm$ 3.2	28.3 $\pm$ 4.4	0.216
ROM (degrees)*	115.5 $\pm$ 16.5	119.5 $\pm$ 17.5	0.343

* Values are expressed as the mean $\pm$ standard deviation, BMI = body mass index, ROM = range of motion

Table 2. Radiographic outcomes of the two groups

Outcomes	Group 1 (n = 30)	Group 2 (n = 37)	p-value
Degree of osteoarthritis**			
Grade II	14 (46.7%)	14 (37.8%)	0.631
Grade III	16 (53.3%)	23 (62.2%)	
Preoperative FTA (degrees)*	168.9 ± 3.2	169.7 ± 2.6	0.544
Postoperative FTA (degrees)*	183.4 ± 3.9	182.2 ± 4.5	0.234
Correction angle (degrees)*,***	14.5 ± 3.5	12.8 ± 4.9	0.114
Union rate (%)	100%	100%	1.000

* values are expressed as the mean ± standard deviation
** Kellgren-Lawrence radiographic grading scale
*** Correction angle = postoperative FTA-preoperative FTA
FTA = femorotibial angle

Table 3. Comparison of medial proximal tibial angles and loss of correction angles between the two groups

Angles	Group 1 (n = 30)	Group 2 (n = 37)	p-value
Preoperative MPTA (degrees)*	85.5 ± 2.8	84.8 ± 3.2	0.350
Postoperative MPTA (degrees)*			
At 1 month	96.7 ± 3.7	95.7 ± 4.0	0.297
At 1 year	95.1 ± 4.7	95.4 ± 3.9	0.776
At 2 years	94.7 ± 4.7	95.5 ± 4.1	0.459
Loss of correction angle (degrees)*			
In the first year	1.6 ± 2.6	0.4 ± 2.6	0.064
In the second year	0.4 ± 1.3	-0.1 ± 2.5	0.325
Overall	2.0 ± 2.7	0.3 ± 3.3	0.026
Loss of correction angle adjusted for age (degrees)*,**			
In the first year	1.9 ± 0.6	0.1 ± 0.5	0.045
In the second year	0.6 ± 0.5	-0.3 ± 0.4	0.193
Overall	2.5 ± 0.7	-0.1 ± 0.6	0.010

* Values are expressed as the mean ± standard deviation
** p-values were analyzed by analysis of covariance (ANCOVA)
MPTA = medial proximal tibial angle

= 0.045). Furthermore, Pearson's correlations coefficients did not demonstrate any correlations between the degrees of correction loss and the subjects' characteristics ($p > 0.05$). In terms of clinical outcomes, a total of 5 out of 67 knees (7.5%) had complications following MOWHTO in our series. In group A, one knee displayed superficial wound infection, which was successfully treated with intravenous antibiotics and one knee displayed a non-displaced fracture of the lateral tibial plateau after falling postoperatively, which was successfully treated by casting. 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. However, there was no deep wound infection, vascular injury or clinically detected deep vein thrombosis in both groups, and no donor-site complication was found in the iliac bone graft-harvested group. All osteotomies were united (Table 2) and no patient required reoperation or a subsequent total knee arthroplasty at the 2-year follow-up.

Regarding inter-observer reproducibility, 0.95, 0.95 and 0.92 intraclass correlation coefficients (ICC) were found for MPTA measurements from standing long, 15- and 10-cm proximal tibial length films, respectively. The intra-observer reliability was 0.98 for techniques of fixation. For the loss-of-correction definitions, Song et al[16] defined loss of correction as a loss of the mechanical axis $\geq 3°$ during the follow-up period. Zorzi et al[19] defined the term as a decrease in anatomical FTA $\geq 4°$. Based on the Coventry finding[20], Miller et al[18] used a value < 8° of tibiofemoral valgus alignment to correlate angular correction with outcome after osteotomy. Chae et al[17] applied the weight-bearing line, described by Dugdale et al[21], which passes at less than 50% of the width of the tibial plateau, to diagnose the correction loss. Compared to our study, if we defined correction loss as a loss of MPTA $\geq 4°$, the loss of correction in group A and B was 23.3% and 8.1%, respectively. Nevertheless, the more important thing was the objective amount of correction loss. This information could be applied to set the overcorrection point during MOWHTO.

To achieve the satisfactory results after MOWHTO, the mechanical and biological factors must be considered. The important mechanical factors consist of the fixation technique and having an intact lateral cortex and lateral soft-tissue hinge[22,23]. Although non-locking T-buttress plates showed significantly better stability than wedge-supported plates in a previous biomechanical study[24], few studies[25] involved MOWHTO performed using this plate in clinical application. Nevertheless, the author[25] used a cancellous bone allograft instead of using autograft and did not show the result of correction loss. In the biological factor, the use of bone grafts to fill gaps can enhance bone healing[1]. Thus, in our T-buttress group, iliac bone grafting was required to provide the adequacy of either mechanical or biological factors to allow the patients to engage in early mobilization.

In the other technique, the fixed-angle plate provides enough strength and is recommended to use without bone graft[1,26,27]. Using the Tomofix™ plate alone; Staubli et al[28] reported that the femorotibial axis was maintained during 1-year follow-up without statistically significant loss of the correction. Pongsoipetch et al[29] showed 0.46-degree loss between follow-up at 1 year and at more than 2 years. None of these studies reported the amount of correction loss, especially during the first year.

In the current study, the use of a non-locking T-buttress plate with autograft augmentation was considered as the conventional technique for MOWHTO at our institute. It was not strong enough to maintain the correction angle and resulted in 1.6° of MTPA loss before the bone united. Additionally, during the remodeling period, a slightly progressive loss of correction angle (0.4°) was shown in the second year after the operation. In contrast, the Tomofix™ group provided adequate stability to the osteotomy without the need for an additional surgical site at the iliac crest. A slight loss of MPTA (0.4°) occurred in the first year, and the osteotomy angle was sustained during the second year postoperatively. Nevertheless, all osteotomies in both groups were united.

Furthermore, although there was a significant difference in age between both methods that may have affected our results, the outcomes still revealed correction loss of greater significance in the first year after using ANCOVA when data were evaluated after age adjustment. Thus, age does not influence the difference in correction loss.

However, the most important factor that regulated the long-term outcome of this procedure was the correction angle after the osteotomy union[3,7]. Therefore, the authors recommend setting the osteotomy angle at an angle greater than the planned overcorrection of 2° if a non-locking compression plate system is selected. In the Tomofix™ system, the desired overcorrection point can be achieved during surgery.

In conclusion, maintenance of the correction angle after MOWHTO depends on the fixation techniques used. The technique using a non-locking plate with bone grafts involved greater loss of correction than the locking plate without any augmentation (2°). Thus, the authors recommend adjusting the osteotomy correction angle in accordance with the selected fixation method to achieve the desired overcorrection.

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Potential conflicts of interest

None.

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การลดลงของมุมที่แก้ไขไปภายหลังการผ่าตัดจัดแนวกระดูกหน้าแข้ง: การศึกษาเปรียบเทียบระหว่างการใช้แผ่นเหล็กดามกระดูกชนิดล็อคกับชนิดไม่ล็อค

จตุรงค์ พรรัตนมณีวงศ์, ทศศาสตร์ หาญรุ่งโรจน์, กีรติ เจริญชลวานิช

ภูมิหลัง: *การผ่าตัดจัดแนวกระดูกหน้าแข้งแบบเปิด (Medial opening wedge high tibial osteotomy) เป็นการผ่าตัดรักษาโรคข้อเข่าเสื่อมที่มีประสิทธิภาพ การลดลงของมุมที่แก้ไขไปภายหลังผ่าตัด (Loss of correction) เป็นภาวะแทรกซ้อนที่พบได้บ่อย และนำไปสู่ผลการรักษาที่ไม่ดี ชนิดของแผ่นดามกระดูกที่ใช้จึงมีบทบาท อย่างมากต่อการลดลงของมุมที่แก้ไขไว้*

วัตถุประสงค์: *เพื่อศึกษาเปรียบเทียบขนาดของมุมที่ลดลงภายหลังการผ่าตัดจัดแนวกระดูกหน้าแข้งระหว่างการยึดตรึงด้วยแผ่นเหล็กดามกระดูก 2 ชนิดที่แตกต่างกัน*

วัสดุและวิธีการ: *จากการเก็บรวบรวมข้อมูลการผ่าตัดจัดแนวกระดูกหน้าแข้งทั้งหมด 67 เข่าในผู้ป่วยจำนวน 54 ราย ระหว่างปี พ.ศ. 2548-2550 แล้วจำแนกออกเป็น 2 กลุ่มคือ กลุ่ม A ใช้แผ่นเหล็กดามกระดูกชนิดไม่ล็อคยึดตรึงกระดูกร่วมกับการใส่กระดูกที่ปลูกถ่ายมาจากกระดูกเชิงกราน (T-buttress plate fixation and autologous tricortical iliac bone graft) และกลุ่ม B ใช้แผ่นเหล็กดามกระดูกชนิดล็อคอย่างเดียว (Locking compression medial high tibial plate fixation) แล้วทำการวัดมุม medial proximal tibial angle (MPTA) จากภาพถ่ายรังสี ก่อนผ่าตัด และที่ 1, 12, 24 เดือน หลังผ่าตัด โดยมุมที่ลดลง (Loss of correction) จะประเมินจากการลดลงของ MPTA ภายหลังผ่าตัด การเปรียบเทียบผลการรักษาระหว่าง 2 กลุ่มใช้ Student's t-test และ Chi-square test*

ผลการศึกษา: *มุมที่ลดลงที่ 2 ปีในกลุ่ม A (2.0 $\pm$ 2.7 องศา) มากกว่าในกลุ่ม B (0.3 $\pm$ 3.3 องศา) (p = 0.026) โดยการลดลง ของมุมในทั้ง 2 กลุ่ม ส่วนใหญ่เกิดขึ้นในปีแรกหลังจากผ่าตัด (1.6 $\pm$ 2.6 องศา และ 0.4 $\pm$ 2.6 องศา ในกลุ่ม A และ B ตามลำดับ) และในปีที่สองพบว่า กลุ่ม A มีมุมที่ลดลงมากขึ้นเล็กน้อย (0.4 $\pm$ 1.3 องศา) ในขณะที่กลุ่ม B มุมค่อนข้างจะคงที่ (-0.1 $\pm$ 2.5 องศา) ภายหลังผ่าตัดจัดแนวกระดูกหน้าแข้งทุกราย มีกระดูกติดดีและมีภาวะแทรกซ้อนโดยรวม 7.5%*

สรุป: *การลดลงของมุมที่แก้ไขภายหลังการผ่าตัดจัดแนวกระดูกหน้าแข้งนั้นขึ้นอยู่กับชนิดของแผ่นเหล็กดามกระดูก ผู้นิพนธ์แนะนำให้แก้ไขมุมให้เพิ่มขึ้นอีก 2 องศา มากกว่ามุมที่ได้วางแผนไว้ถ้าใช้แผ่นเหล็กชนิดไม่ล็อคยึดตรึงกระดูก แต่การเพิ่มมุมนี้ไม่มีความจำเป็นถ้ายึดตรึงกระดูกด้วยแผ่นเหล็กชนิดล็อค*