ORIGINAL RESEARCH

Medial Closing Wedge High Tibial Osteotomy Accurately Corrects Genu Valgum without Iatrogenic Deformity or Complications: A Consecutive Series of Thirty-one Procedures

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Abstract

Introduction: Angular deformities of the tibia and femur lead to mechanical axis deviation (MAD) of the lower limb and malorientation of the joints adjacent to the deformity. The current study analyses the outcomes of using a medial closing wedge high tibial osteotomy (MCWHTO) for the management of genu valgum with high medial proximal tibial angle (MPTA), and combined MCWHTO with lateral opening-wedge distal femoral osteotomy (LOWDFO) in the setting of concomitant genu varum with low lateral distal femoral angle (LDFA).

Methods: There were 18 high tibial osteotomy (HTO)-only and 13 combined HTO + distal femoral osteotomy (DFO) procedures performed. The primary radiographic outcome variables included postoperative MPTA and MAD (in mm). The accuracy of MAD correction was expressed as a percentage. The postoperative posterior proximal tibial angle (PPTA) and limb length discrepancy (LLD) were also measured as secondary radiographic outcome variables. The clinical outcome variables included intraoperative surgical complications (e.g., hinge fracture), all-causes for revision, union rate, time to union, and postoperative knee range of motion. Functional outcomes used included the LDSRS, PROMIS, and EuroQOL scores.

Results: The mean preoperative MPTA was 92.9° (SD = 1.81, range: 88–96). After surgical correction, the mean MPTA was 86.0° (SD = 1.80, range: 83–90) ($p < 0.0001$). The mean preoperative MAD was 32.5 mm (SD = 20.16, range: 10–77) lateral to the centre of the knee joint. The mean postoperative MAD was 2.44 mm medial to the centre of the joint (SD = 7.13, range: 13 medial – 15 lateral) ($p < 0.0001$). The mean change in MAD achieved through surgical correction was 38.16 mm (SD = 17.94, range: 13–77). The accuracy of MAD correction was 96.1% (SD = 0.06%, range: 81.25–100%). The time to unassisted WB was a mean of 75 days (SD = 44.5, range: 44–242).

There was a single stable hinge fracture and one case of chronic regional pain syndrome diagnosed. There were no cases of non-union and no indications for revision surgery in any case.

Conclusion: Medial closing wedge high tibial osteotomy is an effective surgical procedure for the management of genu valgum deformity. The MPTA, LDFA, and MAD can be accurately corrected without significantly altering PPTA or limb length. It may be combined with open lateral distal femoral osteotomy for cases with femoral and tibial contributions to deformity without significantly impacting clinical outcomes. Functional outcomes, specifically relating to self-image are significantly improved after the MCWHTO has been performed.

Keywords: Deformity correction, Distal femoral osteotomy, Genu valgum, High tibial osteotomy, Osteotomy.

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Introduction

Historically, lower limb valgus malalignment was thought to be a femoral-based deformity predominantly. However, new studies have reported that genu valgum originates from the tibia in the majority of patients.[1] Additionally, Eberbach et al. found that a combined femoral- and tibial-based deformity was more common than an isolated femoral-based deformity.[1]

Anatomically, the anteromedial face of the tibia is an accessible location for osteotomy. A supratubercle medial closing wedge high tibial osteotomy (MCWHTO) can correct the deformity, reduce the Q angle and improve patellar tracking.

The current study analyses the outcomes of using a MCWHTO for the management of genu valgum with high medial proximal tibial angles (MPTA), and of a combined MCWHTO with lateral opening-wedge distal femoral osteotomy (LOWDFO) in the setting of concomitant femoral contribution to genu valgum [low lateral distal femoral angle (LDFA)].

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Fig. 1: Two Steinmann pins planning out the wedge to be excised

Methods

This was a retrospective cohort study analysing 31 consecutive procedures in 23 patients undergoing MCWHTO for the management of genu valgum deformity. All cases were performed between February 2018 and October 2022.

Inclusion Criteria

All patients had a genu valgum deformity confirmed on hip-to-ankle long leg radiographs. All patients had a high (>90 degrees) MPTA. Some patients also had a low LDFA leading to a concurrent and contributory distal femoral deformity which was treated with a simultaneous lateral opening wedge distal femoral osteotomy (DFO). These patients were also included in the study. All patients were required to have radiographic outcomes and clinical outcomes available at the time of review in order to be included. Functional outcomes were not a prerequisite for inclusion.

Surgical Technique

The osteotomy is performed through a standard medial mid-sagittal approach to the proximal tibia through the pes anserinus tendons to the level of the bone. A subperiosteal flap is developed anteriorly to the level of the tibial tubercle and developed proximally to allow placement of a retractor underneath the patellar tendon for visualisation while performing the anterosuperior limb of the biplanar osteotomy. Care is taken to avoid entering the joint capsule. A second subperiosteal flap is developed posteriorly at the level of the osteotomy, just distal to the posterior metaphyseal flare of the proximal tibia. This allows for the positioning of a retractor to protect the neurovascular structures at the posterior aspect of the knee.

A 2.4 mm Steinmann pin is then placed under fluoroscopy in the trajectory of the first osteotomy line of the closing wedge, as per the preoperative planning. This typically originates at the flare of the tibial plateau and is aimed towards to the top of the fibular head. During this process, it is important to the have the leg in a neutral position (i.e., patella facing anteriorly) with the Steinmann pin and tibia parallel to the floor. It is important for the pin to end at least 1 cm distal to the tibial plateau to avoid osteotomy propagation into the articular surface. A second 2.4 mm Steinmann pin is then placed under fluoroscopic guidance (Fig. 1). The distance between the two wires is measured with a ruler to replicate the appropriate size wedge thickness according to the preoperative plan. The planned wedge resection width is typically undersized to account for the kerf of the blade which will remove bone and potentially cause an over-correction of the deformity if not accounted for.

The two 2.4 mm Steinmann pins are cut short leaving approximately 1 cm of wire for reference during the osteotomy. A blunt Homan retractor is placed posteriorly in line with the planned trajectory of the osteotomy to protect the posterior structures. A retractor is placed under the patellar tendon to protect it and to allow visualisation of the osteotomy. A 40 mm sagittal saw blade is typically used to make the osteotomy. Care is taken to ensure that the saw blade is perpendicular to the tibial shaft while creating the osteotomy so as to not induce a procurvatum or recurvatum deformity. The saw is stopped frequently to irrigate the bone to minimise the risk for thermal necrosis. As the saw approaches the tibial tubercule, a biplanar osteotomy is made exiting above the insertion of the patellar tendon and also avoiding the knee joint. Once the saw has reached its max depth, a series of osteotomes is utilised serially and in a graduated manner. The osteotome is initially placed to a depth of 40 mm and then fluoroscopy is used to confirm the desired depth to complete the osteotomy. Once both cuts are complete, the wedge of bone is removed.

The initial reduction of the osteotomy is performed manually. This can also be done with a Hintermann distractor or a reduction clamp. Once the reduction is satisfactory a 2.0 mm K-wire is placed across to the hold the reduction. An alignment film is then taken with the use of an alignment rod. A locking medial plate is then applied to the medial tibia. The plate is provisionally fixed in place with two K-wires and fluoroscopy used to confirm satisfactory placement of the plate. The proximal locking screws are placed first. Compression is then applied across the osteotomy either using an articulated tensioning device or placing tibial shaft cortical screws eccentrically through non-locking holes in the plate (Fig. 2). Once

Conflict of interest: None

Patient consent statement: The author(s) have obtained written informed consent from the patient for publication of the case report details and related images.

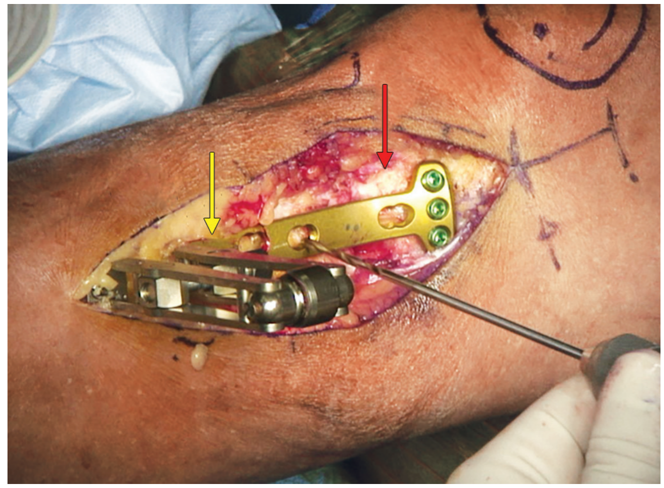

Fig. 2: Articulating compression device attached to the plate (yellow arrow) demonstrating closure of the osteotomy wedge (red arrow) with complete cortical contact

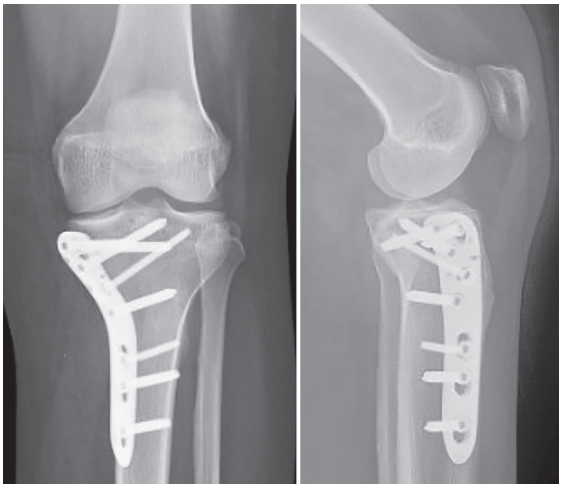

Fig. 3: Locking plate securing the closing wedge osteotomy in position

compression is complete, the fixation continued by the insertion of the remaining locking screws (Fig. 3). A final alignment film is then taken confirming correction of the mechanical axis.

The wounds are irrigated before fascia is closed over the plate. The skin is closed in a layered fashion with an occlusive dressing over the wound. Postoperatively patient is limited to 50 lb weight-bearing for 6 weeks and then progressed to weight-bearing as tolerated slowly over the next 2–6 weeks with the aid of crutches.

Outcomes

The primary radiographic outcome variables included postoperative MPTA and mechanical axis deviation (MAD) (in mm). Mechanical axis deviation was determined on a calibrated long-leg hip to ankle radiograph with the patellae facing forward. The postoperative posterior proximal tibial angle (PPTA) and limb length discrepancy (LLD) were also measured as secondary radiographic outcome variables.

Accuracy of MAD correction was calculated as a percentage value using the following formula:

$$100 - \frac{\text{MAD outside of target correction range (mm)}}{\text{Total planned MAD correction (mm)}} \times \frac{100}{1}$$

For example, if the total planned correction for MAD was 20 mm, the target mechanical axis would then be defined with an acceptable 5 mm zone medial and lateral to the single target point. This gives a normal 10 mm range for correction of the mechanical axis. If the postoperative mechanical axis was 5 mm outside of this target range, the percentage correction accuracy would be calculated as follows:

$$100 - \frac{5}{20} \times \frac{100}{1} = 75\% \text{ accuracy}$$

The clinical outcome variables included intraoperative surgical complications (e.g., hinge fracture), all-causes for revision, union rate, time to union, and postoperative knee range of motion. Functional outcomes were available for a subgroup of the entire cohort. The functional outcome scores used included the LDSRS, PROMIS, and EuroQOL scores.

Statistical Analysis

Demographic data were analysed using descriptive statistics. Interval variables were expressed using mean values, standard deviations (SD), 95% confidence intervals (CI), and ranges. A subgroup analysis comparing outcomes between the high tibial osteotomy (HTO)-only and the HTO + DFO groups was performed. When assessing radiographic, clinical and functional interval variables, the two-sample *t*-test with equal variances was used. A *p*-value of less than 0.05 was taken to be statistically significant. The statistical software used was Stata/IC 13.1 for Mac (64-bit Intel).

Results

The mean age of the group was 41.2 years (SD = 14.99, 95% CI: 34.69–47.66). Approximately 70% ($n = 16$) were female and 30% were male ($n = 7$). The mean BMI of the group was 28.3 (SD = 6.22, 95% CI: 25.63–31.01).

There were 17 right lower limbs and 14 left lower limbs included. Common peroneal neurolysis was performed in 19.3% ($n = 6$) of cases. There were 18 HTO-only and 13 combined HTO + DFO procedures performed. The mean length of stay (LOS) was 3.5 days (SD = 1.43, range: 1–6) for the entire cohort. There was no significant difference in the LOS between the HTO-only and the HTO + DFO cohort (3.38 days vs 3.53 days, respectively, $p = 0.78$). The mean time to follow-up for the entire group was 309 days (SD = 263.42, 95% CI: 212.14–405.39).

For the entire cohort, the mean preoperative MPTA was 92.9° (SD = 1.81, range: 88–96). After surgical correction, the mean MPTA measured 86.0° (SD = 1.80, range: 83–90) ($p < 0.0001$). The mean change in MPTA was 6.9° (SD = 2.25, range: 2–11).

The mean preoperative MAD was 32.5 mm (SD = 20.16, range: 10–77) lateral to the centre of the knee joint. The mean postoperative MAD was 2.44 mm medial to the centre of the joint (SD = 7.13, range: from 13 medial to 15 lateral) ($p < 0.0001$). The mean change in MAD achieved through surgical correction was 38.16 mm (SD = 17.94, range: 13–77). The accuracy of MAD correction was 96.1% (SD = 0.06%, range: 81.25–100%).

In the cohort with a contributory femoral deformity, the mean preoperative LDFA was 84.9° (SD = 4.43, range: 73–90). After surgical correction, the mean LDFA measured 87.12° (SD = 2.42, range: 83–93) ($p = 0.034$). The mean change in LDFA was 3.84° (SD = 4.41, range: 0–15).

There was no significant change induced in the PPTA during operative correction. The mean preoperative PPTA was 83° (SD = 3.83, range: 75–90) compared with a mean postoperative PPTA of 84.4° (SD = 3.82, range: 75–91) ($p = 0.15$).

There was no significant change induced in the LLD during operative correction. The preoperative LLD was 5.9 mm (SD = 8.5, 0–41) compared with a mean postoperative LLD of 2.75 mm (SD = 4.84, 0–24) ($p = 0.09$).

On subgroup analysis, concurrent tibial and femoral deformities had a significantly higher mean preoperative MAD (26.3 mm lateral, SD = 28.6, 14.2–38.4) compared with the tibia-only cohort (9.8 mm lateral, SD = 15.7, 4.2–15.5) ($p < 0.01$). The postoperative MAD in the tibia + femur group was 0.8 mm lateral (SD = 5.7 mm, 95% CI: 3.0 medial – 4.6 lateral) compared with the tibia-only group which measured 5 mm medial (SD = 7.26 mm, 95% CI: 9.2 medial – 0.8 medial) ($p = 0.04$).

When comparing postoperative radiographic outcomes, there were no significant differences between the two groups for MPTA ($p = 0.47$), LDFA ($p = 0.44$), PPTA ($p = 0.13$), or LLD ($p = 0.26$).

Table 1: Preoperative and postoperative functional scores for the LDSRS, PROMIS, and EuroQol

Score	*Preop*	*Postop*	*p-value**
LDSRS (Total)	3.25	3.92	0.006**
LDSRS (Function)	3.30	3.54	0.47
LDSRS (Mental Health)	3.81	4.09	0.27
LDSRS (Pain)	3.35	3.88	0.12
LDSRS (Self-Image)	2.54	3.79	0.0001**
PROMIS (Pain Interference)	58.3	52.4	0.12
PROMIS (Physical Function)	40.4	42.3	0.56
PROMIS (Pain Intensity)	49.4	41.8	0.039
EuroQol	0.67	0.72	0.11
Global Mental Health	52.3	53.8	0.54
Global Physical Health	44.6	47.6	0.29

*Two-sample *t*-test with equal variances. ***$p < 0.05$

There was one single stable hinge fracture which was noted during the procedure and managed with regular HTO fixation. There was one case of chronic regional pain syndrome diagnosed in the postoperative setting. There were no cases of non-union and no indications for revision surgery in any case.

Time to unassisted WB was taken as a surrogate marker for time to union. The time to unassisted WB was a mean of 75 days (SD = 44.5, range: 44–242).

For the entire cohort, the mean preop knee flexion was 123° (SD = 12.4, range: 90–140) compared with a mean postop knee flexion of 120° (SD = 14.2, range: 90–130) ($p = 0.26$). The mean reduction in knee flexion was 5.3° (SD = 9.8, 0–40). The mean preop knee extension was 0.69° (SD = 3.46, range: –5–10) compared with a mean postop knee extension of –0.19° (SD = 0.75, range: –3–0) ($p = 0.17$). The mean reduction in knee extension was 1.58° (SD = 3.24, range: –5–10).

When comparing the tibia-only and the tibia plus femur groups, there was no significant difference in the time to unassisted WB ($p = 0.22$), postoperative knee flexion angle ($p = 0.53$) or postoperative knee extension angle ($p = 0.09$). The preoperative and postoperative functional scores for the LDSRS, PROMIS, and EuroQol scores are demonstrated in Table 1. When comparing the tibia-only and the tibia plus femur groups, there was no significant difference in the postoperative functional scores for any of the functional scores reported in Table 1.

Discussion

Angular deformities of the tibia and femur can lead to MAD of the lower limb and malorientation of the joints adjacent to the deformity.[2] Genu varum and genu valgum increase the risk of medial and lateral compartment osteoarthritis, respectively.[3] Corrective osteotomy at the apex of the deformity allows for angular correction of the deformity which in turn mitigates risk of joint degeneration while simultaneously improving function.[2] A slight overcorrection of the MAD has been shown to produce a 50% reduction in compartment over-loading during gait which improves patient-reported outcomes at 2-years postoperatively.[4,5] Offloading the lateral compartment for valgus deformities is a viable, joint-preserving option for lateral compartment osteoarthritis, especially useful in younger patients hoping to avoid joint replacement surgery.[6] This current study describes the reliable correction of MPTA and MAD with the MCWHTO technique. The accuracy of MAD correction is reported as 96.1% in this cohort. We also report a statistically significant improvement in LDSRS scores specifically related to self-image postoperatively.

The MCWHTOs have the advantage of inherent stability relative to opening-wedge osteotomies (OWO).[7] This is due to direct bone apposition and accelerated bone healing allowing early weight bearing and shorter recovery times than an OWO. A proposed benefit of a MCWHTO relative to a lateral open wedge DFO is that a tibial-based osteotomy alters joint contact forces in both flexion and extension, whereas a femoral-based osteotomy only affects extension.[7,8] However, a recent meta-analysis by van Haeringen et al. found that both can reduce pain and improve knee function.[8] There was no significant difference between OWO and closing wedge osteotomies (CWO) in that study.[8]

The MCWHTO also has the advantage of mitigating the risk of a lateral cortical hinge relative to a medial opening-wedge high tibial osteotomy (MOWHTO). Lateral cortical hinge fractures have been reported to be as high as 25% in MOWHTO and may increase the risk for non-union and postoperative pain.[9] In this current study, we report a single hinge fracture which was managed intraoperatively using the same locking plate at the time of the index procedure.

The literature has been in support of MCWHTO for valgus arthritic knees in patients who wish to remain active and desire to delay arthroplasty.[6,10] Osteotomies are an excellent alternative, joint-preserving, treatment option for these patients. Optimising knee biomechanics can increase the longevity of the native knee joint and improving the anatomical alignment of the knee can also allow for a technically simpler total knee arthroplasty procedure in future, without the need for augments, stems or hinge prostheses. van Lieshout et al. reported on the survivorship and patient satisfaction after MCWHTO in 2020.[7] They analysed 176 patients between 2008 and 2016 reporting that survivorship was approximately 80% at 5-years postoperatively with patient satisfaction at approximately 77%.[7] In that study, 26% developed postoperative knee instability. However, other studies have reported on the use of HTO to correct instability or to correct deformity with concomitant ligament reconstruction.[11] We did not experience any postoperative knee instability as due consideration was given to preserving the MCL during exposure and closure.

A survivorship of 80% is contrary to Mirouse et al. who reported on 19 patients with lateral compartment osteoarthritis (with less than 10° of valgus) who were managed with MCWHTO.[12] They found an overall failure rate of 52% and concluded that there is not a role for HTO in patients with compartment osteoarthritis with <10° of valgus. This current study does report a 100% survivorship but follow-up times are short and so further monitoring of these results will be reported in future.

This present study has several inherent limitations to the study design. First, this is retrospective in nature which limits the accuracy of data recall from documentation at the time of input. Second, radiographic measurements have a degree of subjectivity in their measurement. All measurements were conducted by experts in the field to mitigate error; however, subjectivity and imperfect limb positioning during radiographs remain. Follow-up times are short and so no meaningful long-term clinical outcome conclusions can be made based on this patient cohort yet. Clinical outcomes will be reported in the future at mid- and long-term follow-up. Last, knee range of motion measurements have inherent subjectivity.

Our practice implements usage of a goniometer in clinical measurements to minimise this error.

Conclusion

Medial closing wedge high tibial osteotomy is an effective surgical procedure for the management of genu valgum deformity. The MPTA, LDFA, and MAD can be corrected accurately without significantly altering PPTA or limb length. It may be combined with ipsilateral DFO for cases with femoral and tibial contribution to deformity without significantly impacting clinical outcomes. Functional outcomes, specifically relating to self-image are significantly improved after the MCWHTO has been performed.

Authors' Contributions

Sheridan GA responsible for data analysis, manuscript writing, and editing. Page BJ and Greenstein MD are responsible for data retrieval and manuscript editing. Reif TJ, Fragomen AT, and Rozbruch SR all are responsible for study design and editing.

Ethical Approval

This study is ethically approved by IRB.

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