Acute Correction Of Severe Adolescent Blount's Disease "Tibia Vara" By Single Stage Double Level Corrective Osteotomy Using Internal Fixation

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Abstract

Background: Management of severe adolescent Blount disease is challenging. However, there is a consensus in the literature that early diagnosis and early aggressive surgical treatment are mandatory for a successful treatment and to prevent the progression of the deformity and the development of depression of the medial tibial plateau.

Aim: to assess the clinical and radiological results of acute surgical correction of severe adolescent Blount disease by single stage double level corrective osteotomy with elevation of the depressed medial tibial plateau using internal fixation.

Subjects and Methods: The current prospective study included 20 patients (24 limbs) suffering from severe adolescent Blount disease treated by acute medial tibial plateau elevation, intra-epiphyseal, osteotomy together with another proximal tibial metaphyseal osteotomy to correct the rest of the deformity (remaining varus, internal tibial rotation and procurvatum) using internal fixation implant in the form of proximal tibial locked plate (4.5 mm LCP) applied medially with the aid of cannulated screws for plateau elevation.

Results: The mean pre-operative MTPDA was 31.6°, the mean post-operative MTPDA was 4.95°. The mean pre-operative FTA was 32.75°of varus, the mean post-operative FTA was 2.75° of valgus. The mean pre-operative FC-T angle was 60.5°, the mean post-operative FC-T angle was 92.12°. All of these changes in the radiographic parameters pre and post-operatively were statistically significant (p-value < 0.0001). Clinical assessment at the latest follow-up showed significant improvement of the mean thigh foot angle (TFA) from 29.45° internal rotation pre-operatively to 5.54° external rotation post-operatively, improvement of the mean clinically associated procurvatum deformity from 21.3° of procurvatum pre-operatively to 5.3° of procurvatum post-operatively and improvement of the gait pattern with disappearance of varus thrust during stance post-operatively. All patients retained their pre-operative ROM with no restriction of knee flexion or extension. Also, there was improvement of pain relative to pre-operative assessment in all patients. No significant LLD (< 1.5 cm) was noted at the latest post-operative assessment.

Conclusion: The acute double level osteotomy technique described in the current study for treating patients with severe adolescent Blount disease is considered a technically demanding procedure. Despite these technical difficulties, it gave satisfactory results in terms of restoration of articular surface congruence, correction of the complex multiplanar deformity of the proximal tibia and minimizing or preventing the future recurrence with low incidence of complications, gradual correction by Ilizarov may be reserved for morbidly obese Blount cases with severe deformity to minimize any risk for intra-operative vascular compromise or deformity undercorrection

Keywords: Blount's Disease, Single Stage Double Level Corrective Osteotomy, Internal Fixation

Introduction

Blount disease is a progressive pathological condition characterized by disordered endochondral ossification of the medial proximal tibial physis with subsequent multiplanar deformities of the lower limb (1).

In 1922, Erlacher (2) was credited with the first description of progressive tibial varus deformity in otherwise healthy children.

In 1937, Blount (3) reviewed previous reports with the addition of his own cases. He was the first to identify two forms of this disorder; infantile and adolescent and coined the term “osteochondrosis deformans tibiae”. Although this condition is most commonly referred to as Blount disease, it is frequently referred to as "tibia vara" in the literature.

In 1952, Langenskiold (4) made significant early contributions to the identification and management of infantile Blount disease. He described a prognostic radiographic classification system.

Although Blount coined the term tibia vara referring to only a frontal plane deformity, subsequent authors noted that multiplanar deformities are commonly seen with this condition. Secondary to the asymmetrical growth with relative inhibition of the posteromedial portion of the proximal tibial growth plate, a three dimensional deformity of the tibia with varus, internal rotation and procurvatum (apex anterior) develops along with possible limb shortening in unilateral cases (5, 6).

This pathological condition can lead to a progressive deformity with gait disturbances, limb length inequality, and premature arthritis of the involved knee (7, 8).

Blount disease has two distinct clinical types; early onset and late onset based on whether the onset of the limb deformity develops before or after the age of 4 years (3, 4, 9).

Late onset Blount disease was further classified by Thompson and Carter (9) into juvenile type (onset from 4 to 10 years) and adolescent type (onset after the age of 10 years).

Bilateral affection is common, especially with infantile type (6). Although there are some clinical and radiographic differences between early and late onset Blount disease, there are several similarities, including a predisposition for obese black children. Also, there are comparable histologic findings at the proximal tibial growth plate (9-11).

The prevalence of adolescent Blount disease may reach about 2.5% of the population with high risk particularly in obese black children (12, 13). Incidence may be further rising because of the high prevalence of morbid obesity in western society (14). The male to female ratio is 4:1 and over 90% of patients are obese and black (15, 16).

Adolescent Blount disease has been noted to be commonly associated with distal femoral varus deformity with a reported incidence of 19% to 60%. It is postulated that the medial distal femoral physis may also suffer growth inhibition due to the high loads through the medial knee joint particularly in obese older children with a fat thigh gait (17).

Management of severe Blount disease in adolescents is challenging as patients are usually obese and present with complex deformities of not only tibia vara but also procurvatum, internal tibial torsion, and medial tibial plateau sloping (18, 19). The condition might progress to involve the distal femur and cause instability of the knee and compensatory distal tibial valgus (20, 21).

In these complex cases, a tibial valgus osteotomy is not adequate for correcting the deformity, and additional elevation of the depressed tibial plateau is required (22).

Only few reports were carried out on the use of both the medial plateau elevation and tibial corrective osteotomies combined with ilizarov frame application for the correction of adolescent severe tibia vara. Most of these reports have relied on gradually performed corrections (23-26).

Recently, this could be done acutely with correction of these deformities in a single stage as reported by **Hegazy M et al (27)** in their study. They reported the use of a medial tibial plateau elevation, combined with tibial corrective osteotomy and circular ring Ilizarov fixation of the limb for acute single-stage correction of this complex deformity in severe adolescent Blount disease.

Although ilizarov frame application has some advantages including early weigh bearing and potential correction of multiplanar deformities with simultaneous leg lengthening (28), it is more complicated, time consuming, cumbersome to patients and depends on the cooperation of the patient and their parents. It may cause an adverse psychological impact on some patients. Also, premature consolidation of the proximal osteotomy may occur with very high incidence of pin tract infection. The learning curve for circular frame application can be very steep for clinicians (23, 29).

We aimed at this study to assess the clinical and radiological results of acute surgical correction of severe adolescent Blount disease by single stage double level corrective osteotomy with elevation of the depressed medial tibial plateau using internal fixation.

Subjects and Methods:

This study is a prospective clinical study for patients with severe adolescent Blount disease. All patients underwent acute correction of this complex deformity by performing single stage double level osteotomy at the proximal tibia fixed with plate and screws. An informed consent with the operative details and possible complications was obtained from the patients' parents before surgery. This study included 20 patients with advanced adolescent Blount disease. There were 16 boys and 4 girls, 16 unilateral cases and 4 bilateral cases (24 limbs). Fourteen affected legs were left side and 10 affected legs were right side. All cases underwent surgery at Abo El-Rich Specialized Pediatric Hospital, pediatric orthopaedics unit between 2018-2020. Any other causes of varus deformities around the knee were excluded. No patients were lost for follow up. The average duration of follow up ranged from 6 to 18 months. The mean age at time of surgery was 13 years, with range from 10 years to 17 years. The BMI of each patient was recorded at time of surgical intervention

Inclusion criteria:

Adolescent patients with Blount disease with age ranging from 10 to 17 years, Severe Blount disease with femoral shaft- tibial shaft angle (FTA) ≥ 15° varus, or Significant depression of the medial tibial plateau (MTPDA ≥15°).

Exclusion criteria:

Patients with Blount disease with age below 10 or above 17 years, Mild Blount cases with FTA < 15° varus, Blount disease without significant medial tibial plateau depression (MTPDA <15°), Other causes of varus knee deformities as previous fracture, skeletal dysplasia, also due to physiological, congenital, developmental, and or metabolic causes, Medical contraindication to general anesthesia.

All cases undergone the following:

History:

Careful history taking including age, sex, previous surgeries, nutritional history, presence of ligamentous laxity and family history of similar lower limb malalignment. Any patient's complaint was recorded e.g; medial and lateral knee pain, limping, interference with daily activities, cosmetic concerns due to progressive varus deformity and walking difficulty.

Physical examination:

A full physical examination was carried out for all cases presented with unilateral or bilateral tibia vara in order to rule out other causes of varus deformities around the knee. The limb was examined for neurovascular status and skin condition. Clinical photographs with the patient standing were taken prior to surgery.

The patient's pelvis, knees, and feet were examined carefully. Both lower limbs were examined in the frontal and sagittal planes for asymmetry and alignment. Examination included observational gait analysis to assess varus thrust gait which is defined as accentuation of varus malalignment and lateral knee translation during stance phase which partially corrects during swing. Knee stability was assessed by varus and valgus stress testing of lateral and medial collateral ligaments. Range of motion of the knee (flexion and extension) and quadriceps muscle power were assessed. Rotational profile of the lower limbs was routinely assessed clinically in prone position with 90° knee flexion. The angle of tibial torsion called the thigh foot angle (TFA) was measured between the thigh axis and the hind-foot axis. Negative TFA referred to internal tibial torsion while a positive TFA angle referred to external tibial rotation. Block test was used for assessment of LLD in which blocks of known heights were placed under the short limb with the patient standing till the pelvis was leveled.

Laboratory investigation:

Laboratory investigation including; CBC, calcium, phosphorus, alkaline phosphatase, creatinine and 25-hydroxyvitamin D (25 (OH) D) hormones were requested. They were all within normal range.

Radiographic assessment:

Full length standing anteroposterior radiograph from hip to ankle was obtained with the patella facing forward. Varus malalignment was detected by medial mechanical axis deviation. Femoral shaft-tibial shaft angle (FTA) represented the degree of varus malalignment. Analysis of femoral joint angle, tibial joint angle and JLCA was done to detect the main site of the deformity. The CORA was identified by intersection of the proximal and distal mechanical axes. The angle of depression of the medial tibial plateau (MTPDA) was measured for each case.

Routine anteroposterior and lateral radiographs of the knee and upper tibia were also obtained. All radiographs that were mentioned before were obtained and must be available at the operative theatre.

The following radiographic parameters were assessed and compared between the last pre-operative radiograph and the latest post-operative follow up radiograph for each patient :

- The femoral shaft - tibial shaft angle (FTA) which is the angle between the anatomic axes of the femur and tibia. It was used instead of mechanical axis for assessment of coronal plane alignment.
- Femoral condyle-tibial shaft angle (FC-T angle) which is angle between a line tangential to the lowermost point of both femoral condyles and a line representing the anatomic axis of the tibia.
- Medial tibial plateau depression angle (MTPDA) which is the angle between a line passing tangential to the lateral tibial plateau and another one tangential to the medial plateau.

Management:

All patients underwent acute medial tibial plateau elevation combined with proximal tibial metaphyseal valgus osteotomy. External rotation osteotomy was done also through the proximal tibial metaphyseal cut in 16 cases. A fibular osteotomy was always done in all cases.

All cases required grafting using fibular strut graft from ipsilateral fibula to maintain elevation of the medial tibial hemiplateau.

Surgical technique:

The operation was performed under general anesthesia. Intravenous antibiotic was administered 30 minutes prior to surgery. The patient was operated in a supine position on a radiolucent table.

Pneumatic tourniquet was applied to the midthigh for all cases. The affected limb was sterilized and draped free from the midthigh to the toes. Draping must include the iliac crest so as to be able to check alignment intra-operatively under image intensification using electrocautery cable. Intraoperative fluoroscopy was checked prior to starting to ensure that adequate views could be obtained. The time of surgery ranged from 90 to 150 minutes.

Fibular osteotomy:

About 1.5 to 2.5 cm fibular segment was taken in all patients from ipsilateral fibula through 3 cm lateral incision at the level of the middle to distal third of the leg. Skin, superficial fascia and deep fascia were incised. The plane between the peroneal muscles and the superficial posterior muscles was identified by following the intermuscular septum. Then, the periosteum was incised and the soft tissue was protected using drill sleeve. The osteotomy was started using an oscillating saw in a plane perpendicular to the bone and the osteotomy was completed using a thin sharp osteotome and hammer. The fasciotomy was extended beyond skin incision and the fascia was left open to minimize any risk for compartment syndrome. The skin and subcutaneous tissue were then closed in a routine manner.

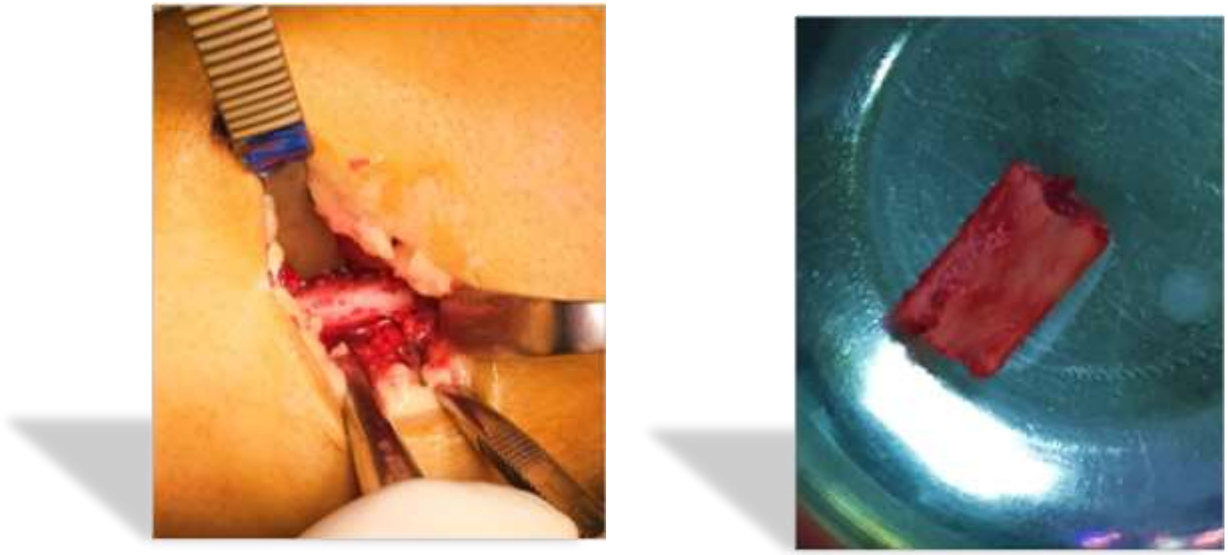

Figure 1: Fibular osteotomy.

Upper tibial osteotomies

An anteromedial curved inverted " J " shaped incision was made staring from the medial knee joint line reaching the tibial tuberosity and curving downwards extending along the anterior margin of the tibia. The incision ensured that the scar will not overly the planned position of the plate and that the plate will be covered by a thick skin flap. The resulting skin flap including skin, subcutaneous tissue and muscle fascia was lifted as full thickness flap. Great care was taken not to damage the saphenous nerve, the sartorius, the medial collateral ligament, the tendons and fascia of the pes anserinus.

The proximal tibial epiphysis and metaphysis were subperiosteally exposed all around to avoid injury of neurovascular structures during osteotomy. Both tibial osteotomies were performed in the same setting through the same anteromedial incision.

Medial tibial plateau elevation osteotomy

Under image intensifier control, the site of the first elevating osteotomy was confirmed by insertion of a pin starting from the posteromedial surface of the proximal tibia just below the curve of the prominent medial plateau directed towards the midpoint of the physis. Multiple drill holes were made in the planned site for osteotomy aiming towards the non-weight bearing intercondylar eminence with great care not to violate the articular surface. One to two shanz screws of suitable size were inserted in the subchondral part of the medial tibial hemiplateau to be used as a lever after osteotomy to aid in plateau elevation. With the use of a sharp thin osteotome and hammer, the osteotomy was completed in the same previously prepared plane. The depressed medial tibial plateau was elevated using the pre-inserted shanz screws and with the aid of the osteotome. During osteotomy, the knee was flexed to reduce the risk for neurovascular injury.

The epiphyseal part was cracked using the osteotome as a lever to elevate the medial tibial plateau taking care not to violate the hinge of the articular cartilage. When the medial tibial plateau was seen under image intensifier to be leveled with the lateral tibial plateau, temporary fixation of the elevated medial tibial plateau was done by advancing the shanz screws into the lateral tibial hemiplateau. Guide wires were used and passed subchondral through both medial and lateral tibial plateaus. The excised fibula was used as a strut for supporting the new tibial plateau position with respect to articular cartilage continuity. One to two 6.5 mm cannulated fully threaded cancellous screws were used through the previously inserted guide wires to maintain the newly elevated medial tibial plateau position. Then, guide wires and shanz screws were removed.

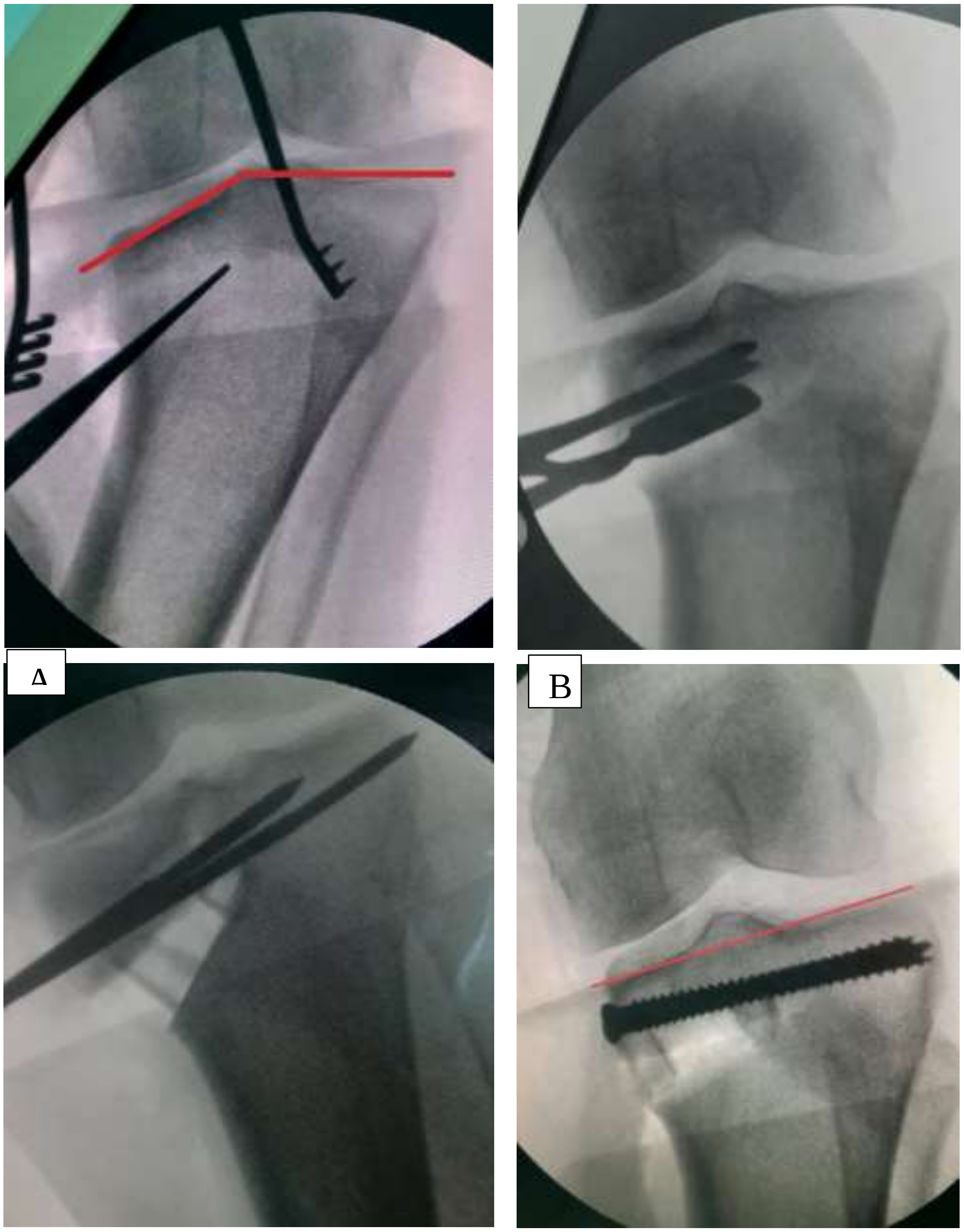

Figure 2: (A, B, C &D) Steps for medial tibial plateau elevation osteotomy respectively.

Upper tibial metaphyseal osteotomy

The second distal osteotomy was an open wedge osteotomy. It was performed in the proximal tibial metaphysis about 5 cm below the knee joint line which was nearest to the site of CORA. It was done just distal to tibial tuberosity to avoid injury to physis of the tibia and the tuberosity to avoid recurvatum deformity.As in the first epiphyseal osteotomy and with image intensifier control, multiple drill holes were made and directed in a transverse plane from medial to lateral tibial cortex. An oscillating saw was initially used then osteotomy was completed by a sharp thin osteotome. The sequence of deformity correction proceeded as follows: translation, derotation, angulation and lastly extension if procurvatum was present.

After the osteotomy was completed, the distal segment was displaced laterally in the planned direction of translation, it was then externally rotated to correct the torsional deformity until the second toe of the plantigrade foot became aligned with the patella. Angulation was corrected with overcorrection of 5-10° valgus to reduce pressure on the medial proximal tibial physis aiming to avoid recurrence. Open wedge osteotomy was preferred being technically easier as the incision and fixation were both done from the medial side.

Preliminary fixation with shanz screws or k-wires was done to hold the new corrected position till plate application.The mechanical axis of the limb was checked using the electrocautery cable stretched between the hip and ankle joint. Under image intensifier, its proximal end was seen at the center of the hip joint and its distal end was at the center of the ankle joint; correction was accepted when it crossed the center of the knee joint. Proximal tibial locked plate (4.5 mm LCP) was applied medially to stabilize the new corrected position with the interposed fibular strut graft in the elevating osteotomy. Then, the preliminary shanz screws or k-wires were removed. The tourniquet was released then peripheral circulation and limb perfusion were checked prior to finalizing plate fixation. The surgical wound was closed in a classic fashion after drain insertion with special care not to close the fascia to avoid compartment syndrome. No further external immobilization was needed in all cases during the current study.

(A) (B) (C)

Figure 3: (A&B) Intra-operative image intensifier views of the two upper tibial osteotomies (medial tibial plateau elevation osteotomy and upper tibial metaphyseal osteotomy with interposed fibular graft). (C) intra-operative photograph; white arrow refers to epiphyseal elevation osteotomy with interposed fibular strut graft and blue arrow refers to metaphyseal open wedge osteotomy.

Post-operative management:

Post-operative radiographs including anteroposterior and lateral radiographs of the knee and upper leg, were ordered. Patients were encouraged to do active knee exercises once the postoperative pain was relieved. Weight bearing was not allowed until radiological signs of bone healing. The patients were discharged from the hospital mostly on the third day post-operatively after removal of the drain and confirmation of good peripheral circulation. Follow up was done in the outpatient clinic. The first follow up visit was after 2 weeks for stitches removal. The patients were reassessed clinically and by radiographs at 1, 2, 3, 6 and 12 months post-operatively. Partial weight bearing was allowed 6 to 8 weeks post-operatively and full weight bearing was allowed 10 to 12 weeks post-operatively after complete bony healing.

Full length standing anteroposterior radiograph from hip to ankle was taken after complete bony healing and full weight bearing. Plates and screws were not routinely removed and in the current study, no cases required elective plate removal till the latest follow up at 18 months. The patients were allowed to start passive and active knee ROM exercises, as well as quadriceps strengthening exercises. Closed chain kinetic exercises in the form of active and passive heel slides in bed as well as knee flexion and extension in the sitting position were instructed early after surgery. Radiographs were then repeated to start progressive weight-bearing accordingly and full weight bearing was allowed when consolidation of both osteotomies was achieved.

Post-operative evaluation parameters:
Clinical evaluation: including LLD, thigh foot angle, correction of associated procurvatum, gait, lateral thrust, knee range of motion, quadriceps function and pain. Radiographic assessment of the previously mentioned angles; FTA, FC-T angle and MTPDA pre and post-operatively.

Statistical analysis
All data were collected, tabulated and statistically analyzed using SPSS 25 for windows (SPSS Inc., Chicago, IL, USA) qualitative data were expressed as absolute frequencies (number) & relative frequencies (percentage). Data were expressed as number and percentage for qualitative variables. Chi –square test (X^2) was used to calculate difference between qualitative variables. The threshold of significance is fixed at 5% level (p- value). p-value < 0.05 was considered statistically significant (S) results. p-value < 0.01 was considered high statistically significant (HS) results. p-value ≥ 0.05 was considered statistically insignificant (NS) results

Results

There were 4 girls (4/20) and 16 boys (16/20). The mean age at presentation was 13 years, with a range from 10 to 17 years with SD ± 1.77, Sixteen patients (16/20) presented with unilateral affection and 4 patients (4/20) presented with bilateral affection. Fourteen legs (14/24) were affected on the left side and 10 legs (10/24) on the right side. The mean BMI of patients at time of surgery was 34.5 kg/m2 (range from 28 to 43) with SD ± 10.52

Table 1 Demographic and characteristics of studied cases

	Range	**Mean ± S. D**
Age / year	10 – 17	13 ± 1.77

Gender	N	%
Male	16	80
Female	4	20
Total	20	100
Laterality	N	%
Unilateral	16	80
Bilateral	4	20
Total	20	100
Side	N	%
Right	10	42
Left	14	58
Total	24	100

The mean MTPDA changed from 31.6° pre-operative (range from 15°-50°) with SD ± 10.92 to 4.95° post-operative (range from 0°-16°) with SD ± 5.27. This post-operative improvement in the mean MTPDA is statistically significant (p-value < 0.0001).

Table 2; Comparison between pre and post-operative values as regard MTPDA.

MTPDA	**Pre-operative**	**Post-operative**
Range	**15° – 50°**	**0° – 16°**
Mean ± SD	**31.6° ± 10.92**	**4.95° ± 5.27**
T. test	**11.295**	
P. value	**< 0.0001**	

The mean FTA changed from -32.75° pre-operative (range from -15° to -45°) with SD ± 10.05 to 2.75° post-operative (range from -13° to 13°) with SD ± 6.76, in which positive values indicate a valgus angle and negative values indicate a varus angle. This post-operative improvement in the mean FTA is statistically significant (p-value < 0.0001).

Table 3; Comparison between pre and post-operative values as regard FTA.

FTA	**Pre-operative**	**Post-operative**
Range	**-15° – -45°**	**-13° – 13°**
Mean ± SD	**-32.75° ± 10.05**	**2.75° ± 6.76**
T. test	**14.353**	
P. value	**< 0.0001**	

The mean FC-T angle changed from 60.5° pre-operative (range from 46° to 84°) with SD ± 10.46 to 92.12° post-operative (range from 82° to 102°) with SD ± 6.53. This post-operative improvement in the mean FC-T angle is statistically significant (p-value < 0.0001).

Table 4; Comparison between pre and post-operative values as regard FC-T angle.

FC-T angle	**Pre-operative**	**Post-operative**
Range	**46° – 84°**	**82° – 102°**
Mean ± SD	**60.5° ± 10.46**	**92.12° ± 6.53**
T. test	**12.555**	
P. value	**< 0.0001**	

The mean LLD changed from 2.08 cm pre-operative (range from 0.5 to 3) with SD ± 0.7 to 0.76 cm post-operative (range from 0 to 1.5) with SD ± 0.51. This post-operative improvement in the mean LLD is statistically significant (p-value < 0.0001). However, in all cases the LLD at the final follow up was not significant (<1.5cm).

Table 5; comparison between pre and post-operative values as regard LLD.

LLD	**Pre-operative**	**Post-operative**
Range (cm)	**0.5. – 3**	**0 – 1.5**
Mean ± SD	**2.08 ± 0.7**	**0.7 ± 0.51**
T. test	**6.818**	
P. value	**< 0.0001**	

The mean TFA changed from -29.45° pre-operative (range from -10° to -48°) with SD ± 11.49 to 5.54° post-operative (range from -10° to 12°) with SD ± 6.70, in which positive values indicate external tibial rotation and negative values indicate internal tibial rotation. This post-operative improvement in the mean TFA is statistically significant (p-value < 0.0001).

Table 6; comparison between pre and post-operative values as regard TFA.

TFA	**Pre-operative**	**Post-operative**
Range	**-10° – -48°**	**-10° – 12°**
Mean ± SD	**-29.45 ± 11.49**	**5.54 ± 6.70**
T. test	**12.8333**	
P. value	**< 0.0001**	

The mean clinically measured procurvatum changed from 21.3° pre-operative (range from −5° to 35°) with SD ± 13.71 to 5.3° post-operative (range from −5° to 20°) with SD ± 7.16, in which positive values indicate clinical procurvatum and negative values indicate recurvatum. This change in the mean clinically measured procurvatum angle pre and post-operatively is statistically significant (p-value < 0.0001).

Table 7; comparison between pre and post-operative values as regard clinical procurvatum angle.

Procurvatum angle	Pre-operative	Post-operative
Range	**-5° – 35°**	**-5° – 20°**
Mean ± SD	**21.33° ± 13.71**	**5.33° ± 7.16**
T. test	**5.068**	
P. value	**< 0.0001**	

Gait, knee range of motion and pain:

All patients reported improvement in their gait pattern post-operative. Varus thrust during gait was noticed in 12 cases (14 limbs) pre-operative but it significantly improved in all cases post-operative except some residual lateral thrust in two bilateral cases with undercorrected deformity.

All patients retained their range of motion for the knee within the pre-operative range. All patients were able to achieve active and passive full knee flexion and extension during follow-up with good quadriceps function.

Although pain was not a dominant complaint in this entity, improvement of pain relative to the pre-operative assessment was noted in all patients.

Ability to bear weight post-operatively (stability of the osteotomy and fixation):

Partial weight bearing using elbow crutches was allowed 6 to 8 weeks post-operative and full weight bearing was allowed 10 to 12 weeks post-operative after complete bony healing with consolidation of both osteotomies

Maintenance of correction till the last follow up:

All osteotomies healed with no re-fracture or loss of correction at the latest follow up.

Time for bone healing:

All cases healed within 8 to 10 weeks post-operative with complete bony consolidation with 12 weeks post-operative with no pain at osteotomy sites.

Complications:

There was one case of deep wound infection detected 1 week after surgery in the first post-operative follow up visit which was successfully treated by surgical debridement, irrigation and IV/oral antibiotics.

Overcorrection of the varus deformity into slight valgus occurred in one unilateral case due to improper intra-operative assessment of mechanical axis correction. Nevertheless, the patient and his parents were satisfied and he had a normal painless gait.

Undercorrection of the deformity (including varus, internal tibial rotation and procurvatum) occurred in two bilateral obese cases (4 limbs). In one of them, optimum correction of all deformities was obtained intra-operative but vascular compromise occurred which was detected intra-operative after releasing tourniquet during final assessment of deformity correction and before finalizing plate and screws placement. The limb became markedly less perfused, more cold, capillary refilling was delayed and distal pulses were not felt. Therefore, we had to decrease the magnitude of deformity correction to regain the distal circulation which resulted in undercorrection of the deformity in theses limbs. The other case was properly aligned intra-operative while the patient supine on the operating table but post-operative standing clinical photograph and full length radiograph, which had been done after complete bony healing, showed undercorrection of the deformity.

Residual lateral thrust during gait occurred in the 2 previously mentioned undercorrected bilateral obese cases. However, the overall satisfaction with procedure from the patients and their parents were good.

Vascular compromise was recorded also in another unilateral case at the end of surgery and before wound closure when tourniquet was released. However, there was some bleeding that was allocated to the open cancellous bone, the distal pulses were significantly diminished, the capillary refilling was delayed and the foot became more pale and cold. With assessment of the the plate position and screws lengths by image intensifier, a long posteriorly directed screw was noticed in the lateral knee view with image intensifier. Immediate exchange with another shorter one was done. Within 30 minutes after screw exchange, the limb perfusion was improved with improvement of capillary refilling time and coolness was diminished and lastly the distal pulses returned. Post-operative strict observation of the distal circulation was done.

Two patients developed hypertrophic scar formation, one of them, who developed deep wound infection, mentioned before, that was managed by surgical debridement. The other one who had previous failed surgery with high tibial osteotomy through the same scar.

There were no neurologic complications encountered in this series and no recorded cases with compartment syndromes. There were no cases of septic arthritis of the knee or joint stiffness.

No cases developed delayed union or nonunion. No recurrence of the deformity, refracture, implant failure or significant LLD were recorded till the latest follow up.

Pre-operative (A) clinical photograph of lower limbs, (B) AP right knee radiograph and (C) full length standing lower limb radiograph

Case study:Male patient, 13 years old at time of presentation, with unilateral right sided late onset Blount disease. His parents started to notice the deformity 2 years before. They reported that no family history of similar condition and no previous surgical interventions. All laboratory investigations were within normal. Acute intra epiphyseal osteotomy for medial plateau elevation with interposed fibular strut graft (from ipsilateral fibula) was done followed by metaphyseal open wedge osteotomy in the same setting. Fixation was done by LCP 4.5 mm proximal tibial plate.

(A)

(B)

(C)

Post-operative radiographs: (A) immediately post-operative, (B&C) at 2, 6 months follow up respectively.

Post-operative clinical photographs & (C) full length standing AP radiograph at 9 months follow up.

Discussion

In advanced Blount cases, the tibia can translate laterally with the medial femoral condyle falling into the posteromedial depression, causing a varus thrust in the stance phase of gait. Hence, elevation of the medial tibial plateau is recommended for these cases for favorable outcome.

The current study evaluates the clinical and radiological results of acute surgical correction of severe adolescent Blount disease by single stage double level corrective osteotomy using plate and screws as a method of fixation for both osteotomies. The first intra-epiphyseal osteotomy for elevation of the depressed medial tibial plateau and restoring joint congruity in order to prevent premature degenerative changes of the knee joint. The second metaphyseal osteotomy is an open wedge osteotomy for correction of residual metaphyseal varus ± internal tibial torsion and procurvatum if present. Fibular ostectomy was done as a routine in all cases in this study using the excised fibular segment as a strut for maintaining elevation of the medial tibial plateau precluding external immobilization and allowing for early post-operative ROM due to rigid internal fixation.

The degree of medial tibial plateau (MTP) depression that requires elevation is controversial. According to **McCarthy et al (25)**, MTP depression should be corrected when slope exceeds 15°. However, according to **Schoenecker et al(30)** and **Fitoussi et al (26)**, it should be corrected when depression exceeds 30°. In the current study, MTP elevation was performed when MTPDA > 15°.

Bone grafting in medial tibial plateau elevation is controversial. Most authors used bone grafting to support the elevated MTP and enhance healing. This included either, the bony wedge removed from the valgus wedge osteotomy, tricortical iliac graft, the bony fragment removed from the precedent fibular osteotomy, or tricortical iliac allograft **(25, 31).** In this study, the bony fragment removed from the precedent fibular osteotomy was used. Other authors did not use bone grafting, as they used rigid external fixator with gradual correction for both osteotomies in which the system was sufficiently rigid to maintain elevation. The gap left under the MTP was progressively filled over a period of a few months. However, there is a must to wear the external fixator for longer periods **(26, 32).**

In the current study, a straight cut medial opening wedge osteotomy was used for the distal metaphyseal cut allowing more axial deformity correction and is much simpler to perform than a closing wedge as the incision and fixation were both done from the medial side and allows more freedom in correction of angular and torsional deformity. However, the opening wedge osteotomy type has been reported in the literature to be associated with high nonunion rates, long period of weight bearing restriction, and potential leg lengthening, but these drawbacks were not an issue in the current study with no reported cases of non-union or significant LLD at the latest follow up. Also, closing wedge osteotomy was reported to cause limb shortening which may require further leg length equalizing procedures, despite it have the advantage of rapid bony healing. Other osteotomy types as focal dome osteotomy (FDO) that was described by **Hankemeier et al (33)** and **Paley et al (34),** is a bone cut that represents an arc of a circle, the center of which is centered on the center of rotation of angulation (CORA). The advantages of the FDO are adjustability, large bone to bone contact and stability. The disadvantages are the technical difficulty and its incompatibility with correction of axial rotation. However, in the study by **El Rosasy and Ayoub (35),** they did not find any benefit of FDO over straight cut osteotomy in their series of 36 bone segments in 27 patients. Moreover, straight cut osteotomy is easier to perform than an FDO.

In the current study, a proximal tibial LCP was used as the method of fixation together with cannulated screws and performed several functions. It secures both the medial tibial plateau elevation and metaphyseal osteotomies, provides a buttress effect to the elevated medial condyle being applied to the medial surface; the proximal screws, either cannulated or through the plate, traverses the epiphysis from medial to lateral sparing the physis as much as possible. The plate also provides rigid internal fixation that precludes postoperative immobilization, allows early knee ROM and improves patient’s post-operative satisfaction. The plate also offered sufficient rigidity of fixation that avoided loss of correction previously reported with screw-only or k-wire fixation **(36).**

Regarding lower limb length, the issue of LLD in Blount cases aroused much discussion in the literature. The etiology of LLD, if any, is both the growth disturbance and the deformity. In bilateral symmetric cases, LLD is not usually a problem and lengthening is not usually indicated. In unilateral or bilateral asymmetric cases, LLD may be significant, especially in younger patients. The expected LLD at the skeletal maturity, should be predicted from bone age and growth curves. Depending on the case, it could be prevented or lessened either by; a simultaneous epiphysiodesis of the contralateral proximal tibia and fibula or an ipsilateral pre-emptive overlengthening according to the expected LLD **(25, 28, 37)**. In the current study, the minimum age for surgery was 10 years, therefore, there was no need for these additional procedures and at the latest follow up, no significant LLD (<1.5 cm) was noted with significant improvement of the mean shortening from a pre-operative value of 2.08 cm (range from 0.5 to 3 cm) to 0.76 cm post-operative (range from 0 to 1.5).

The results of this study will now be compared to the findings of previous studies using the same double osteotomy principle for complex proximal tibial deformity in advanced Blount disease whether performed acute or gradual, with either internal or external fixation:

Schoenecker et al (30) reported in their study, the results of elevation of medial tibial plateau in patients with severe Blount disease. The study included seven children (7 limbs) between 10 and 13 years. Elevation osteotomy was done acutely through an open approach and fixation was done using internal fixation implants (wires, plates and screws). The osteotomy defect was filled with bone graft. Proximal tibial metaphyseal osteotomy was performed concomitant with the elevation of the medial tibial plateau in three patients, before the elevation in three, and after the elevation in one patient. A concomitant epiphysiodesis of the lateral tibial plateau and proximal fibula was added in the same setting to all cases. The mean FTA was corrected from 25° varus pre-operative (range from 2° to 55° varus) to 4° valgus post-operative (range from 5° varus to 10° valgus). The mean FC-T angle was corrected from 62° pre-operative (range from 40° to 77°) to 89° post-operative (range from 81° to 94°). The mean MTPDA was corrected from 43° pre-operative (range from 32° to 50°) to 10° post-operative (range from 0° to 20°).

Regarding clinical evaluation at the latest follow up, **Jones et al (23)** reported that no patients had pain, medial or lateral instability, lateral thrust during gait and the knee range of movement at the final follow up was from 0° to at least 110° knee flexion. Three patients out of the 7 included cases needed further tibial lengthening by modification of ilizarov frame after hemiplateau elevation and in 1 patient, leg length equalization was gained by an epiphysiodesis of the contralateral distal femur and proximal tibia. There were no problems with nonunion at the site of the osteotomy. Premature consolidation of the osteotomy for elevation of the hemiplateau occurred in three patients.

Regarding radiographic evaluation, the mean FTA had corrected from 33.6° varus (range from 24° to 45° varus) pre-operative to neutral (4° varus to 10° valgus) post-operative. The mean FC-T angle had increased from 46˚ (range from 40° to 52°) pre-operative to 87˚ (82° to 90°) post-operative. The mean MTPDA had reduced from 41˚ (range from 30° to 50°) pre-operative to 11˚ (range from 6° to 20°) post-operative. The above improvements were all statistically significant ($p < 0.001$).

Van Huyssteen et al (38) reported their experience with double elevating osteotomy for late-presenting Blount's disease. Their study included 24 children with 34 affected knees. The mean age of patients at time of surgery was 9.1 years (7 to 13.5 years). Both osteotomies, an elevation osteotomy for medial plateau and a metaphyseal barrel-vault "dome" proximal tibial osteotomy, were done acutely through an open approach in a single stage procedure. Tricortical iliac crest and fibular grafts were used for hemiplateau elevation. The tricortical wedge is held in place with Kirschner wires cut flush with bone and the metaphyseal osteotomy. Fixation was done using smooth wires cut flush to bone and the distal osteotomy was held using two crossed Steinmann pins cut flush with bone. Above knee cast was used post-operatively for 6 weeks. A concomitant lateral epiphysiodesis of proximal tibia and fibula was also performed to prevent recurrence.

Regarding their clinical evaluation, 21 knees out of the 34 knees were in neutral or slight valgus at follow-up. Thirteen were in slight varus but were satisfied with the result. At the latest follow up, all knees were stable and had a full range of movement. There was no lateral thrust during gait. The TFA ranged from 10° to 25° of external rotation. No patient had a LLD greater than 1 cm.

Complications include wound sepsis in 2 patients, one resulting in wound breakdown requiring a split-skin graft. One tibia required further an extension osteotomy for failure to correct anterior tibial bowing fully, 15 months after the first operation.

In their study, there was significant improvement in the radiographic parameters. The mean FTA was corrected from 30.6° pre-operative to 0° to 5° of valgus post-operatively in 29 of the 34 knees. Five knees were undercorrected and had residual varus of 2° to 5°. The mean MTPDA was corrected from 49° (range from 40° to 60°) pre-operative to 26° (range from 20° to 30°) post-operatively.

In the study by Hefny et al (24) which included 5 patients with 7 affected limbs with neglected tibia vara, they performed double osteotomy technique, one osteotomy to elevate the depressed medial plateau, and another osteotomy to correct the rest of the deformity. Both osteotomies were done at the same session through an open approach. Correction was done gradually using the Ilizarov Frame. The mean age at time of surgery was 11.6 years (range 8 to 15 years).

Clinically, all patients were maintaining full extension of the knee at the final follow-up. The range of flexion changed from an average of 130° pre-operatively to an average of 125- at the final follow-up. The

gait pattern was improved significantly in all patients. Pin tract infection was encountered in all patients but improved with antibiotics and pin site care.
Radiologically, the mean FTA was corrected from 36° varus pre-operatively (range from 20° to 47° varus) to 4° of varus post-operatively (range from 12° varus to 3° valgus). The mean FC-T angle was corrected from 58° pre-operative (range from 45° to 75°) to 83° post-operatively (range from 78° to 90°). The mean MTPDA was corrected from 53° pre-operatively (range from 27° to 82°) to 10° post-operatively (range from 2°to 20°).
Hefny H and Shalaby H (32). reported their series of 8 patients (12 limbs) using the same technique of double elevating osteotomy that was mentioned before in the discussion regarding their previous study in 2006 but their surgical technique was modified to be more safe by using the pulling force of Giggly saw for performing intra-articular osteotomy instead of hammering on the curved osteotome which could cause an inta-articular fracture. The mean age at time of surgery was 9 years.
Three patients (5 limbs) were grossly overweight with a body mass index (BMI) of more than 25. All patients had full range of movement in the knee and were walking with a considerable lateral thrust, in particular those with a BMI of more than 25. Clinically, all patients were maintaining full extension of the knee at the final follow-up, and all patients noticed a significant improvement in them gait pattern. Clinically, all patients were maintaining full extension of the knee at the final follow-up, and all patients noticed a significant improvement in them gait pattern. Clinically, the preoperative range of movement of the knee joint was maintained within 5° in all patients. All patients were maintaining full extension of the knee at the latest follow-up. All patients noticed a significant improvement in the gait pattern. Pin tract infection occurred in 4 limbs.
Radiologically, the mean FTA was corrected from 36° varus pre-operatively (range from 26° to 54° varus) to 5° varus post-operatively (range from 14° varus to 4° valgus). The mean FC-T angle was corrected from 58° pre-operatively (range from 46° to 66°) to 84° post-operatively (range from 77° to 90°). The mean MTPDA was corrected from 63° (range from 45° to 85°) pre-operatively to 8° post-operatively (range from 0° to 15°).
McCarthy JJ et al (25) reported in their retrospective study, the safety and efficacy of single stage acute medial plateau elevation with concurrent tibial gradual osteotomy for severe or relapsing Blount disease. Fixation was done using a multiplanar external fixator. The study included 16 patients (22 limbs). The mean age of the children at time of the index procedure was 8.8 years (range from 6.8 to 11.8 years). Medial plateau elevation was done with medial sloping, typically of 15° or more. Tricortical allograft was used for maintaining plateau elevation.
All radiographic measurements in their study improved significantly at the final follow up ($P < 0.05$). The mean FTA improved from 29° varus (range from 10° to 64° varus) pre-operatively to 3° of valgus (range from 21° varus to 14° valgus) post-operatively and the MTPDA improved from 37° (range from 15° to 63°) pre-operatively to 12° (range from 0° to 24°) post-operatively.
Complications included pin site infection in 3 patients who were treated by long-term antibiotics; one of them had a proximal pin exchanged for a possible septic knee. Two patients needed fixator adjustments, and 1 patient noted pain during the period of distraction, and distraction was temporarily halted then reinstated. There was undercorrection in 5 patients at follow up with FTA greater or equal to 10° varus. This was explained to be the result of primary recurrence at the site of the tibial osteotomy and not the plateau elevation.
Their results were similar to those of van Huyssteen et al who found recurrence of the tibial deformity, not the plateau deformity, but felt that it was due to a delayed or incomplete epiphysiodesis of the lateral proximal tibia, although there was no radiographic evidence to strongly support or disprove that presumption.
Gkiokas A et al (28) reported their experience with double osteotomy technique for acute correction of tibial deformity in combination with medial plateau elevation for the management of neglected Blount disease cases. Their series included eight children (9 limbs) with a mean age of 12 years (range from 9 to14 years). Both osteotomies were performed simultaneously in every case through an open incision; one

for medial plateau elevation combined with the insert of bone graft and one for the correction of tibial deformity. Fixation is achieved by staples, Steinmann pins, K-wires, and plates. Both the bony wedge removed from the first osteotomy and the excised fibular segment were used as a strut for supporting the new medial plateau position. The limb was immobilized with a long-leg cast until the osteotomies were healed.

Hegazy M et al (27) reported in their prospective study, their clinical experience and results of single-stage acute correction of the complex proximal tibial deformity in severe adolescent Blount disease using a minimally invasive surgical approach. Their study included 13 patients with 19 limbs affected with adolescent Blount disease. The mean age at time of surgery was 14 years. The first osteotomy limb was used to elevate the depressed medial tibial plateau, while the second limb osteotomy corrected the metaphyseal varum and internal rotation deformity. This acute correction was stabilized by an Ilizarov frame construct.

Radiographically, there was statistically significant improvement in the measured angles durning the latest post-operative assessment ($P < 0.005$). The MTPDA improved from a median of 38° (range from 27° to 56°) pre-operatively to 7° (range from 0° to 11°) post-operatively. The FTA improved from a median of 34° varus (25° to 41°) pre-operatively to 2° varus (range from 5° varus to 5° valgus) post-operatively. The FC-T angle improved from a median of 54° (range from 42° to 78°) pre-operatively to 86° (range from 82° to 92°) post-operatively.

Othman M et al (39) evaluated in their study, which included 10 cases (14 limbs) with severe early onset Blount disease, the outcome of simultaneous medial tibial plateau elevation and metaphyseal osteotomy using Ilizarov fixator. Both were performed through an open approach. The elevation osteotomy was further supported by fibular graft which was cut into two segments and the taller one was inserted in the posterior part of the osteotomy for correction of posteromedial slope and the shorter one anteriorly. The medial plateau depression and internal tibial rotation deformity were corrected acutely. The varus, procurvatum and shortening were corrected gradually, by distraction osteogenesis. The mean age at time of surgery was 10.3 years (9 to 13 years)

Clinically, at the latest follow up assessment, there was no restriction of knee movement. All knees were stable except two knees, which showed a moderate coronal instability. The gait (including lateral thrust and in-toeing gait) showed a significant improvement. There was notable improvement in pain. All patients returned to a higher activity level. All patients and parents were satisfied with the final outcome. The mean shortening improved from a preoperative value of 3 cm (2.5 – 4cm), after a (1 to 3 cm) preemptive over-lengthening, to a final value of 1cm (0 -1.5 cm).

All radiographic parameters were improved significantly. The FTA changed from 35° varus pre-operatively (range from 25° to 49° varus) to 0.9° valgus (range from 5° varus to 3° valgus) post-operatively at the final follow up. The MTPDA changed from 38° (range from 32° to 57°) pre-operatively to 7° (range from 2° to 9°) post-operatively at the final follow up assessment.

Complications included pin tract infection (10 limbs), temporary foot drop (one limb), and distal osteotomy delayed union (two tibias).

In **Fitoussi F et al (26)** study , 6 patients with 8 affected knees were managed in a single stage comprising medial tibial plateau elevation osteotomy, lateral hemi- epiphysiodesis and proximal tibia osteotomy to correct varus and rotational deformity. The procedure was performed through an open approach. No bone graft was needed to support medial plateau elevation and fixation was achieved using an Ilizarov external fixator. Mean age at surgery was 10.5 years. Fibular osteotomy was done in order to allow satisfactory valgization.

Clinically, mean thigh foot angle improved from 4° internal rotation pre-operatively to 9° external rotation post-operatively at the final follow up. The mean LLD at the latest follow up was < 11mm. The mean knee flexion was 136° without flexion contracture.

Radiologically, they did not use FTA for coronal plane alignment assessment. Instead, they used the HKA (hip knee ankle), which is the obtuse angle subtended between a line from the centre of the femoral head to the centre of the knee and another line from the the centre of the knee to the centre of the ankle. The mean

HKA improved from 151° (range from 135° to 165°) pre-operatively to 179.6° (range from 162° to 185°) at the latest follow up post-operatively. The mean MTPDA improved from 42° (range from 34° to 50°) pre-operatively to 5.4° (range from 0° to 12°) at the latest follow up.
Complications included one common peroneal nerve palsy, resolved within three months, one premature fibular consolidation during lengthening, leading to proximal tibiofibular subluxation, one deep infection, requiring surgical revision, one necrosis around the external fixator wires, requiring local pin care and antibiotic therapy. Recurrence of varus deformity was recorded in one patient.
Baraka MM et al (40) reviewed their prospective case series of 19 patients (21 knees) with severe Blount's disease who underwent a single-stage medial tibial plateau elevation and metaphyseal osteotomies, with internal fixation. The mean age at time of surgery was 10.3 years (range from 8.2 to 13.6).
Clinically, the mean thigh foot angle improved from 27° internal rotation pre-operatively to 11° external rotation post-operatively. All cases maintained full knee extension, no limitation in flexion range of movement and no signs of instability or lateral thrust gait. No cases of deformity recurrence were identified at their latest follow-up.
Radiologically, all the radiographic parameters improved significantly ($p < 0.001$). The mean FTA improved from 29° varus (range from 15.5° to 51° varus) pre-operatively to 7° valgus (range from 5° to 9.5° valgus) post-operatively, the MTPDA improved from 38.3° (range from 21.5° to 53°) pre-operatively to 2.4° (range from 0° to 6.6°) post-operatively. No significant LLD was detected at the latest follow-up (< 1 cm).
Regarding post-operative complications in the study by **Baraka MM et al (40),** one patient developed a superficial infection at the proximal end of the surgical wound which was resolved with antibiotics and dressings alone. Two patients had irritation by prominent hardware at the proximal tibia who needed elective plate removal later on. Two patients developed hypertrophic scar formation. No cases of deformity recurrence, hardware failure, transient or permanent neurologic injury were found till the latest follow-up
As regarding the associated procurvatum deformity in the current study, the clinically associated procurvatum deformity angle was improved from a mean of 21.3° procurvatum pre-operatively to a mean of 5.3° procurvatum post-operatively. This significant improvement is nearly similar to the finding of **Kim SJ and Sabharwal S (41),** in their study regarding improvement in the procurvatum angle in Blount cases following surgical correction but, in their study the mean improvement in radiographically measured procurvatum (8.2°) was larger than that measured for clinically measured procurvatum (3.8°). Therefore, they reported that visual inspection of the extremity can underestimate the procurvatum deformity of the proximal tibia relative to the measurable deformity on radiographs.
Post-operative complications in the current study were minor when compared with other studies that used the same combined osteotomy technique. Post-operative deformity undercorrection was recorded in two bilateral cases of the current study, with recorded reversible intra-operative vascular compromise in one of them. It was noticed that, the two bilateral cases had morbid obesity (BMI > 35) with severe deformity which may raise our concern that acute combined osteotomy technique with internal fixation utilized in the current study may be not suitable for those morbidly obese patients with severe deformity in which gradual correction may be preferred for them. Consequently, further studies including large series of similar cases may be needed to confirm or disprove our observation.
Although, the previously described techniques for medial tibial elevation were associated with potential risks of intra-articular fractures, medial condyle displacement and inadequate plateau elevation with persistent lateral laxity, these complications were not recorded in the current study **(25, 32).** Furthermore, other studies conducting gradual elevation with Ilizarov have reported various complications, including pin-site irritation, interference with rehabilitation, pin-tract infection, pin breakage, premature consolidation, psychological upset, undercorrection and deformity recurrence (23, 24, 45, 104).
The technique in the current study had achieved a greater mean elevation of the MTP (mean post-operative MTPDA of 4.95°) compared with studies employing gradual distraction. Compared with the current study, the previously reported technique with gradual correction has achieved a mean post-operative MTPDA of 8° with a mean FTA of 4°varus **(32).**

A single-stage double elevating osteotomy with internal fixation was infrequently discussed in the literature. In the study by **Gkiokas et al (28)** which was mentioned before, they conducted acute MTP elevation and metaphyseal osteotomies on a series of 8 patients (9 limbs). A closing wedge was resected from the metaphyseal osteotomy that was used to support MTP elevation. They relied on staples, Kirschner-wires and plates for fixation of the metaphyseal osteotomy, and Kirschner-wires for the elevated MTP with post-operative plaster immobilization in all cases. Mechanical axis alignment was not used to assess their correction and recurrence; instead, they relied on the FTA as in the current study. The technique they reported started first with the metaphyseal osteotomy, achieving correction of the FTA of 10° to 15°, before correcting the medial plateau depression and restoring joint congruence which might affect reliability of assessment of limb alignment. At their latest follow-up, only two limbs had a valgus FTA of only 2°, while the rest remained in varus undercorrection ranging from 1° to 8° varus. Their final mean MTPDA was 10°, in two limbs the angles were 18° and 22° and in the rest of the seven limbs, the angles ranged from 2° to 9°. Their principle for correction is different from our presented technique in the current study where joint congruence is restored first followed by correcting mechanical alignment through the metaphyseal osteotomy so that the depressed MP and joint incongruence would not affect measurement of overall limb alignment. This would also eliminate the possible change to corrected limb alignment after MTP elevation. Also, performing a lateral closing wedge metaphyseal osteotomy would further increase the limb shortening with the potential for significant LLD particularly in unilateral cases. The opening wedge osteotomy used in the current study can be regarded as more of a length-preserving technique.

The current study has several limitations. The maximum follow-up period in this study was 18 months. However, most patients are approaching skeletal maturity at their latest follow-up. Despite satisfactory outcome regarding the joint congruence and limb alignment, longer-term evaluation will be needed for confirmation of LLD at full skeletal maturity to determine if any length-equalizing procedures are required and also to assess for the occurrence of any premature knee arthritic changes. Tibiofemoral disproportion secondary to premature tibial epiphysiodesis needs to be addressed in further studies.

Conclusion

Management of severe adolescent Blount disease is challenging. However, there is a consensus in the literature that early diagnosis and early aggressive surgical treatment are mandatory for a successful treatment and to prevent the progression of the deformity and the development of depression of the medial tibial plateau.

The acute double level osteotomy technique described in the current study for treating patients with severe adolescent Blount disease is considered a technically demanding procedure. Despite these technical difficulties, it gave satisfactory results in terms of restoration of articular surface congruence, correction of the complex multiplanar deformity of the proximal tibia and minimizing or preventing the future recurrence with low incidence of complications. Nevertheless, extra care must be taken during surgery to avoid injury of the adjacent neurovascular structures that could provoke serious complications. These preventive measures mainly include knee flexion with adequate subperiosteal dissection of the proximal tibial epiphysis and metaphysis prior to osteotomy, also releasing tourniquet and checking vascular status before finalizing plate fixation. Furthermore, gradual correction by Ilizarov may be reserved for morbidly obese Blount cases with severe deformity to minimize any risk for intra-operative vascular compromise or deformity undercorrection.

Single-stage medial tibial plateau elevation and metaphyseal osteotomies with rigid internal fixation by plate and screws, significantly improved the clinical and radiographic parameters in severe Blount disease with no need for post-operative additional external immobilization and avoiding the adverse effects of gradual distraction by Ilizarov external fixator frame, with no evidence of deformity recurrence till the latest follow up. Therefore, this procedure could be considered as a reliable solution for treating complex deformity of severe adolescent Blount disease with associated medial tibial hemi-plateau depression.

To our knowledge, there are no long term follow-up studies for series of patients treated by this technique to clarify the superiority of this technique over other techniques in terms of preventing or delaying deformity recurrence, assessing the need for future limb equalizing surgeries or detecting early degenerative changes in the adult life.

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References

1. **Sabharwal S.** Blount disease. J Bone Joint Surg Am. 2009;91(7):1758-1776.
2. **Erlacher P.** Deformierende prozesse der epiphysengegend bei kindern. Archiv für orthopädische und Unfall-Chirurgie, mit besonderer Berücksichtigung der Frakturenlehre und der orthopädisch-chirurgischen Technik. 1922 Mar;20(1):81-96.
3. **Blount WP.** Tibia vara: osteochondrosis deformans tibiae. JBJS. 1937 Jan 1;19(1):1-29.
4. **Langenskiöld A, Riska EB.** Tibia vara (osteochondrosis deformans tibiae): a survey of seventy-one cases. JBJS. 1964 Oct 1;46(7):1405-20.
5. **Siffert RS, Katz JF.** The intra-articular deformity in osteochondrosis deformans tibiae. JBJS. 1970 Jun 1;52(4):800-4.
6. **Sabharwal S, Lee Jr J, Zhao C.** Multiplanar deformity analysis of untreated Blount disease. Journal of Pediatric Orthopaedics. 2007 Apr 1;27(3):260-5.
7. **Hofmann A, Jones RE, Herring JA.** Blount's disease after skeletal maturity. The Journal of bone and joint surgery. American volume. 1982 Sep 1;64(7):1004-9.
8. **Zayer M. O**steoarthritis following Blount's disease. International orthopaedics. 1980 Jun;4(1):63-6.
9. **Thompson GH, Carter JR, Smith CW.** Late-onset tibia vara: a comparative analysis. Journal of pediatric orthopedics. 1984 Mar 1;4(2):185-94.
10. **Lovejoy JR JF, Lovell WW.** Adolescent tibia vara associated with slipped capital femoral epiphysis: a report of two cases. JBJS. 1970 Mar 1;52(2):361-4.
11. **Wenger DR, Mickelson M, Maynard JA.** The evolution and histopathology of adolescent tibia vara. Journal of pediatric orthopedics. 1984 Jan 1;4(1):78-88.
12. **Henderson RC, Kemp GJ, Hayes PR.** Prevalence of late-onset tibia vara. Journal of pediatric orthopedics. 1993 Mar 1;13(2):255-8.
13. **Noonan KJ, Price CT, Sproul JT, Bright RW.** Acute correction and distraction osteogenesis for the malaligned and shortened lower extremity. Journal of Pediatric Orthopaedics. 1998 Mar 1;18(2):178-86.
14. **Golding JS, McNeil-Smith JD.** Observations on the etiology of tibia vara. The Journal of Bone and Joint Surgery. British volume. 1963 May;45(2):320-5.
15. **Ingvarsson T, Hägglund G, Ramgren B, Jonsson K, Zayer M.** Long-term results after adolescent Blount's disease. Journal of pediatric orthopedics. Part B. 1997 Apr 1;6(2):153-6.
16. **Kling Jr TF. Angular deformities of the lower limbs in children.** The Orthopedic clinics of North America. 1987 Oct 1;18(4):513-27.
17. **Thompson GH, Carter JR.** Late-onset tibia vara (Blount's disease). Current concepts. Clinical orthopaedics and related research. 1990 Jun 1(255):24-35.
18. **Cook SD, Lavernia CJ, Burke SW, Skinner HB, Haddad Jr RJ.** A biomechanical analysis of the etiology of tibia vara. J Pediatr Orthop. 1983 Sep 1;3(4):449-54.
19. **Loder RT, Johnston 2nd CE**. Infantile tibia vara. Journal of pediatric orthopedics. 1987 Nov 1;7(6):639-46.
20. **Kline SC, Bostrum M, Griffin PP.** Femoral varus: an important component in late-onset Blount's disease. Journal of pediatric orthopedics. 1992 Mar 1;12(2):197-206.
21. **Schoenecker PL, Rich MM. The lower extremity.** Lovell and Winter's pediatric orthopaedics. 5th ed. Philadelphia: Lippincott Williams and Wilkins. 2001;2001:1059-4.
22. **Gregosiewicz A, Wośko I, Kandzierski G, Drabik Z.** Double-elevating osteotomy of tibiae in the treatment of severe cases of Blount's disease. Journal of pediatric orthopedics. 1989 Mar 1;9(2):178-81.
23. **Jones S, Hosalkar HS, Hill RA, Hartley J.** Relapsed infantile Blount's disease treated by hemiplateau elevation using the Ilizarov frame. The Journal of bone and joint surgery. British volume. 2003 May;85(4):565-71.
24. **Hefny H, Shalaby H, El-Kawy S, Thakeb M, Elmoatasem E.** A new double elevating osteotomy in management of severe neglected infantile tibia vara using the Ilizarov technique. Journal of Pediatric Orthopaedics. 2006 Mar 1;26(2):233-7.
25. **McCarthy JJ, MacIntyre III NR, Hooks B, Davidson RS.** Double osteotomy for the treatment of severe Blount disease. Journal of Pediatric Orthopaedics. 2009 Mar 1;29(2):115-9.
26. **Fitoussi F, Ilharreborde B, Lefevre Y, Souchet P, Presedo A, Mazda K, Penneçot GF.** Fixator-assisted medial tibial

plateau elevation to treat severe Blount's disease: Outcomes at maturity. Orthopaedics & Traumatology: Surgery & Research. 2011 Apr 1;97(2):172-8.

27. **Hegazy M, Abdelatif NM, Mahmoud M, Khaled SA, Abdelazeem AH, El-Sayed MM, Karim MM, Elshazly O.** Correction of severe adolescent tibia vara by a single-stage V-shaped osteotomy using Ilizarov fixator. European Orthopaedics and Traumatology. 2015 Jun 1;6(2):99-105.
28. **Gkiokas A, Brilakis E.** Management of neglected Blount disease using double corrective tibia osteotomy and medial plateau elevation. Journal of children's orthopaedics. 2012 Oct 1;6(5):411-8.
29. **Pandya NK, Clarke SE, McCarthy JJ, Horn BD, Hosalkar HS**. Correction of Blount's disease by a multi-axial external fixation system. Journal of children's orthopaedics. 2009 Aug 1;3(4):291-9.
30. **Schoenecker PL, Johnston R, Rich MM, Capelli AM. E**levation of the medical plateau of the tibia in the treatment of Blount disease. The Journal of bone and joint surgery. American volume. 1992 Mar 1;74(3):351-8.
31. **Robbins CA.** Simultaneous Correction of Medial Proximal Tibial Plateau Depression and Tibia Vara in an Obese Child with Blount's disease. Case 66, In Rozbruch SR, Hamdy RC (eds.), Pediatric Deformity, Springer International Publishing Switzerland, 2015.
32. **Hefny H, Shalaby H**. A safer technique for the double elevation osteotomy in severe infantile tibia vara. Strategies in trauma and limb reconstruction. 2010 Aug 1;5(2):79-85.
33. **Hankemeier S, Paley D, Pape HC, Zeichen J, Gosling T, Krettek C.** Die kniegelenknahe Focal-dome-Osteotomie. Der Orthopäde. 2004 Feb;33(2):170-7.
34. **Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A.** Deformity planning for frontal and sagittal plane corrective osteotomies. Orthopedic Clinics of North America. 1994 Jul 1;25(3):425-66.
35. **El-Rosasy M, Ayoub M.** Acute correction of proximal tibial deformities in adolescents using Ilizarov external fixator: focal-dome versus straight-cut osteotomy. Journal of Pediatric Orthopaedics B. 2007 Mar 1;16(2):113-9.
36. **Rab GT.** Oblique tibial osteotomy for Blount's disease (tibia vara). Journal of pediatric orthopedics. 1988 Nov 1;8(6):715-20.
37. **Bar-On E, Weigl DM, Becker T, Katz K.** Treatment of severe early onset Blount's disease by an intra-articular and a metaphyseal osteotomy using the Taylor Spatial Frame. Journal of children's orthopaedics. 2008 Dec 1;2(6):457-61.
38. **Van Huyssteen AL, Hastings CJ, Olesak M, Hoffman EB.** Double-elevating osteotomy for late-presenting infantile Blount's disease: the importance of concomitant lateral epiphysiodesis. The Journal of bone and joint surgery. British volume. 2005 May;87(5):710-5.
39. **Othman M, Abdelwahab AM, Abdelfattah M.** Treatment of severe early-onset Blount's disease by simultaneous medial hemiplateau elevation and metaphyseal osteotomy using the Ilizarov fixator. International Journal of Orthopaedics. 2018;4(3):486-93.
40. **Baraka MM, Hefny HM, Mahran MA, Fayyad TA, Abdelazim H, Nabil A.** Single-stage medial plateau elevation and metaphyseal osteotomies in advanced-stage Blount's disease: a new technique. Journal of children's orthopaedics. 2021 Feb 1;15(1):12-23.
41. **Kim SJ, Sabharwal S.** Is There a Difference in Sagittal Alignment of Blount's Disease Between Radiographic and Clinical Evaluation. Clinical Orthopaedics and Related Research®. 2014 Dec;472(12):3807-13.