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# Genu Varum in Children; Various Treatment Modalities for Bowleg's Correction: Review article

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## ABSTRACT

**Backgound:** Genu varum (Bowlegs) is among the most prevalent lower-limb misalignments correlated with pain and impairment, and it continues to be a source of concern for parents. Corrective osteotomy is generally performed on children with pathologic genu varum (GV) deformities to rectify the deformity. The treatment's purpose is to get the knee back to its normal mechanical axis. Non-surgical therapy is recommended in children under the age of three since it is difficult to distinguish between physiological bowing and early tibia vara. Various osteotomy techniques have been used, including closing wedge lateral tibial osteotomy, dome osteotomy, and opening wedge medial osteotomy.

**Objective:** The current review aimed to figure out a better, less expensive, and more pleasant way to keep the open wedge of valgus tibial osteotomy for GV malformation without adding expense, an unsightly scar or requiring a re-operation for implant removal.

**Methods:** PubMed, Google scholar and Science direct were searched using the following keywords: Genu varum, osteotomy, open and closed wedge osteotomy and autologous fibular strut. The authors also screened references from the relevant literature, including all the identified studies and reviews, only the most recent or complete study was included.

**Conclusion:** Despite technological advances and new surgical operation. The treatment of GV deformity in kids is still a serious concern for parents. Various osteotomy techniques have been used, including closing wedge lateral tibial osteotomy, dome osteotomy, and opening wedge medial osteotomy. Autologous fibular strut graft is an excellent, if not superior, graft for open wedge medial tibial osteotomy because of its strength, durability in preserving correction, cost-effectiveness, ease of graft harvest, and restricted incision and pain sites.

**Keywords:** Genu varum, Osteotomy, Open and closed wedge osteotomy, Autologous fibular strut.

## INTRODUCTION

Genu varum (GV) is a Latin term referr to Bowlegs. It's one of the most prevalent lower-limb misalignments linked to pain and dysfunction. However, minimal attention has been paid to limb position and muscle actions while doing tasks in patients with GV [1]. This condition can appear at any age, from infancy to maturity, and it can be caused by a variety of factors. As the condition worsens, the patient may develop lateral knee thrust and a waddling gait. There may be in-toeing as well as subsequent consequences on the hip and ankle [2].

Its pathogenesis is both physiologic and pathologic. In physiologic GV, the condition is self-limiting and normally requires just clinical follow-up. However, in pathological situations, the disease often progresses over time, predisposing to mechanical lower limb difficulties as well as joint disorders [3]. The physiologic form is still the most frequent globally, with nutritional rickets coming in second and other causes being uncommon or even exceedingly rare. Systemic disorders like achondroplasia, vitamin D-resistant rickets, renal osteodystrophy, and osteogenesis imperfecta may also be associated with GV [4].

Intervention indications are not usually properly defined. Focal fibrocartilaginous dysplasia is an uncommon condition that typically does not require treatment. Several surgical techniques for pathologic GV have been documented, including proximal tibial osteotomy, hemi epiphysiodesis, asymmetric physeal distraction, and medial tibial plateau elevation. The primary objective of therapy is to reestablish the mechanical axis of the limb [5].

The most popular GV correction procedures are open and closed high tibial osteotomies. Numerous approaches have been utilized in children to preserve the open wedge of the medial tibial osteotomy. Iliac crest grafts, orthopaedic plates and screws, and artificial bone replacements are a few examples [6].

The downsides of an iliac crest transplant include the need for surgery at a remote location, pain, an unsightly scar, and infection. On the other side, bone replacements are costly and add to the expense of what appears to be a straightforward treatment, as well as an additional burden in a poor country. Utilizing plates and screws will necessitate a second operation to remove the implant [7].

The current review aimed to figure out a better, less expensive, and more pleasant way to keep the open wedge of valgus tibial osteotomy for GV malformation without adding expense, an unsightly scar or requiring a re-operation for implant removal.

### Genu varum (GV):

GV (tibia vara) is a varus malformation identified by outward knee bending that implies the lower leg is bent inside with relation to the thigh's axis, giving the limb the image of an archer's bow (Figure 1). The femur and tibia are typically angled medially [8].



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**Figure (1):** Preoperative anteroposterior X-ray view of both lower limbs with GV [8].

GV is relatively prevalent in children and could be a source of concern in parents. A variety of illnesses might be to blame, and the natural history of the deformation may range from relatively benign, physiological bending that requires just comfort and monitoring to far more complicated, pathological reasons that necessitate early treatment to avoid further deformities and handicaps. As a result, it is critical to have a thorough grasp of typical variances and frequent reasons of tibial bending in evaluating and managing with successful therapy as needed [9].

The formation of the tibiofemoral angle in kids follows a typical sequential process as per age, as documented in detail in an early radiological investigation of **Salenius and Vankka** [10]. Kids are typically birth having considerable knee varus that generally diminishes as maturity. The knees straighten at 12-18 months, then develop to significant valgus over the second and third years. From the age of six, the valgus normalizes to adult levels. However, there is a large variety of standard deviations around this curve at any particular age.

**1. Types of GV:**

GV is physiologic in newborns and babies, peaking between 6 and 12 months. The tibiofemoral angle approaches zero between 18 and 24 months of normal growth, following which it becomes a physiologic genu valgus. Eventually attaining the adult configuration by the age of six to seven years old. After the age of two, GV is deemed abnormal. Angular malformations are more common in youngsters. It is almost always of benign origin [7].

***Physiological tibial bowing:***

The first varus found in infants under the age of two is termed as 'physiologic varus', and it is the most prevalent reason for GV in toddlers. A few kids might lay outside the usual curve yet still exhibit physiological varus, especially those who start walking early at a young age, becoming ambulant before their first birthday. Bowing is often bilateral and symmetrical, however, one side may be more affected than the other. Although, most children walk effectively, this may be accompanied by an in-toeing stride that predisposes them to stumble. Internal tibial torsion is commonly seen in conjunction with physiologic GV and generally corrects along with the varus deformation. On radiographs, the femoral and tibial physis are normal, and there is typically bending of the entire lower leg without the need for an acute angular element [9]. For children with physiological varus, no active treatment is necessary; even significant GV above thirty can be corrected with continued growth. Because most cases resolve spontaneously by the age of three, parental reassurance and occasional examination are all that is necessary [9].

***Pathological GV:***

Pathological GV is almost always of benign origin. The most prevalent cause of pathological bending in kids is idiopathic tibia vara [7]. Pathology is more likely to be the underlying cause of GV if it is unilateral, appears just after the age of three years, is a fast-increasing malformation, drastic, related with shortening (of the limb or stature), related with a varus push of the knee when walking, and observed in conjunction with overweight. When physiological varus is present, and the bone is not entirely ossified, radiograph interpretation before the age of three years is frequently challenging. As a result, it is difficult to identify physiological varus from pathological varus in children under the age of 18 months utilizing imaging.

There are various pathological causes for GV that must be considered.

**Killen and DeKiewiet** [9] reported that if a kid is unwell, whether, from rickets or another factor that hinders bone ossification or is malnourished, the bowed condition may continue. Thus, rickets is the most common cause of this malformation. Skeletal abnormalities, infection, and tumors can all impact leg development, resulting in one-sided bow-leggedness. The other reasons include occupational, particularly among jockeys, and physical trauma, with the disease extremely likely to reoccur following incidents affecting the femoral condyles.

***The following are the most often recognized pathological reasons*:**

(1) Blount's disease, (2) Metabolic bone disease: Rickets, nutritional or X-linked hypophosphataemic rickets and renal (Osteodystrophy), (3) Trauma, (4) Osteomyelitis, (5) Skeletal dysplasias (Achondroplasia, pseudoachondroplasia and metaphysis and (6) Focal fibrocartilaginous dysplasia [11].

**2. Clinical evaluation:**

While diagnosing a child with GV, a comprehensive history should be obtained, such as when the deformation was first noticed and if it seems to be stationary or progressing. A previous medical and development background, especially how old the child was when they started to walk and whether the other developmental changes were fulfilled appropriately, should be documented. Previous severe traumas or infections, as well as medical or nutritional concerns, should be noted in the history, indicating an associated metabolic imbalance. The family background might reveal comparable limb malalignment and familial bone disorders in other family members since it increases the likelihood of associated metabolic bone disease or skeletal dysplasia, especially if the child's length is less than the twenty-fifth centile [11]. Inquire about the patient's and family's perception of the problem: is it merely aesthetic, or do they experience discomfort or limitations in their activities? [12].

The physical examination begins with an examination of overall health and diet. Following the registration of the kid's height, weight, and age percentiles, a comprehensive evaluation of the kid's pelvis, knees, and feet must be performed. Both limbs must next be checked in both the frontal and sagittal planes for symmetrical, joint passive range of motion, and rotational profile, with specific emphasis devoted to the existence of tibial torsion. A child stands with a modest bending of the hips and knees, as well as outward rotation of the legs. It might produce the appearance of bent legs, and tibia vara can be misdiagnosed. As a result, when assessing GV, whether radiographically or medically, it is critical to overlook the foot position and instead twist the hips till the patella is pointing forward with the knee completely extended. The degree of varus can be assessed using serial clinical photographs or a goniometer. On projectional radiography, the hip-knee-ankle angle, which is an angle between both the femoral mechanical axis and the center of the ankle joint, can be used to quantify the extent of varus or valgus deformation. Adults often have a varus of 1.0° to 1.5°. In children, normal ranges differ [13].

If GV is found, the symmetry of the deformity should be analyzed, and the degree of the deformity must be defined by calculating the intercondylar distance between the two knees using goniometers. It is important to determine if the varus is a progressive deformation or the result of a sudden angulation; if the angulation is sudden, it must be confined to the femur, knee, or tibia. Knee stabilization, especially the integrity of the lateral ligament complex, must be evaluated.

**3. Complications of untreated GV:**

PHMM tears are associated to the intrinsic varus deformation of the knee [14]. Anterior cruciate ligament (ACL) damage can be related to GV [15]. Varus deformity causes an abnormal distribution of the weight. The stress is concentrated medially, accelerating degenerative changes causing medial compartment osteoarthritis [16].

**4. Treatment modalities:**

In general, there is no need for treatment for idiopathic presentation because it is a normal anatomical variance in the younger child. When it lasts more than three and a half years, treatment is recommended. While rickets causes unilateral presentation or gradual worsening of the curvature, the essential thing is to manage the constitutional condition while also directing the caregiver not to set the kid on his feet [17].

The objective of treatment is to provide a well-aligned lower limb with normal joint orientation and equal leg lengths, which lasts through skeletal maturity [18]. The treatment technique includes bracing, osteotomy of the tibia and fibula, osteotomy and epiphysiodesis of the lateral tibial condyle and the proximal end of fibula, osteotomy and resection of bony bar or osteotomy, the elevation of the medial tibial condyle and epiphysiodesis [19].

***Bracing:***

The basic idea of orthotic therapy in infantile tibia vara is to change the aberrant compressive pressures so that normal growth may continue and the GV can be rectified. Brace therapy should be explored in all patients < two and half years old with early Blount's disease alterations (Langenskiöld stages I, II) and in cases older than two years old with chronic bowing and Blount's disease risk factors [19]. Recent research has shown that brace therapy can address both the varus deformity and the pathologic proximal-medial tibial growth disruption. The best outcomes were obtained when the deformity was unilateral. Bilateral deformity, obesity, feminine gender, and a low socioeconomic condition are all poor predictors of bracing success [19].

**5. Surgical treatment:**

The surgical treatment of GV is indicated when the deformity is progressive, uncomfortable, or debilitating. The aims of the operation are to reduce discomfort (if found) and to align the limbs with a horizontal knee joint for weight-bearing [20].

***Osteotomy:***

The osteotomy in GV is most commonly utilized in three or four-years-old children who have elevated risk factors for recurrence, such as obesity, female gender, and an increased medial physeal slope, as well as child 30 to 36-months old who is a poor candidate for brace treatment and for the 3-year-old kid who is having persistent GV despite brace treatment. This posture reduces compression over the disordered physis and allows normal development to continue [20]. An osteotomy can be created by percutaneous drill using manual osteoclasis, open drilling, or an oscillating saw with irrigation to avoid heat necrosis. Crossed K-wires or Steinmann pins, plaster pins, staples, plating, and external fixation are also possibilities [12]. The extent of overcorrection is chosen by the surgeon's discretion, although it is often five to ten degrees greater valgus angulation than is appropriate for the kid's age. Overcorrection should not be performed on a kid who does not have risk factors since this might result in a permanent or even worsening valgus deformity. This is analogous to the valgus deformity that develops in a young kid following a proximal tibial metaphyseal fracture [19].

Several approaches for doing this surgery on youngsters have been documented. The osteotomy is always placed distal to the tibial tubercle to avoid injury to the tibial apophysis and consequently genu recurvatum. To allow sufficient correction of the GV and internal tibial torsion, a concomitant osteotomy of the fibula is required [19].

**Surgical treatment included preoperative, intraoperative, and postoperative components:**

***Preoperative planning should include the following:***
Determination of the mechanical axis deviation (in mm from the center of the knee joint) prior to surgery. Identification of the etiology of the misalignment: the femur, tibia, joint laxity, or any combination of these factors, and determination of the severity of the abnormality

**Open wedge osteotomy:**
When a limb is short, an opening wedge osteotomy (OWO) with a bone graft can be used to lengthen it. There are two types:

***(1) Open wedge osteotomy proximal to the tibial tuberosity (OWOPT):***

**Technique:** Beginning at the anteromedial border of the tibia and ending at the superior border of the tibial tubercle, a guide wire is inserted. The wire is inserted and directed towards the tip of the fibular head, one centimeter below the lateral articular surface. The guide wire's position is evaluated using fluoroscopy. To minimize proximal migration of the osteotomy into the joint, the tibial osteotomy is done immediately distal to the guiding pin. The sagittal plane slope of the osteotomy is crucial, and it should resemble the proximal tibial joint slope. Under direct observation, a tiny oscillating saw is utilized to cut the tibial cortex from the tibial tubercle around to the posteromedial corner [21].

Gradually thin flexible osteotomes are employed with intermittent fluoroscopy to progress the osteotomy to within 1 cm of the lateral tibial cortex. The osteotomy's mobility is evaluated by gently manipulating the leg with a valgus force. If the opening is inadequate due to valgus stress, two or three osteotomies can be stacked up at the osteotomy site to produce the necessary opening while minimizing the risk of intra-articular fractures. The wedges are then pushed into the osteotomy and steadily advanced until the appropriate opening is attained [22].

The sagittal plane must be evaluated fluoroscopically and directly. The tibia has a triangle form, and the anterior opening must be < the posteromedial opening to retain the anatomic slope. If the medial ligamentous apparatus is very tense, we execute a soft tissue release distally by detaching the long fibers of the medial collateral ligament from the tibia through subperiosteal detachment. Full-extension was required and is of the utmost significance. If the osteotomy is done above the fibular head, the fibula and tibiofibular joint do not need to be disrupted since the tethering effect is lost [21].

***Advantages of OWOPT:***

- Because of the cancellous nature of this part of the tibia, the bone repair is rapid.
- Because it is near to the Cora level, it is more successful in correcting the deformity.
- Fibular osteotomy is not necessary since the osteotomy is oriented towards the head of the fibula, removing the tethering effect [23].

***Disadvantage of OWOPT:***

- It cannot be performed on cases with an open growth plate.
- It has a lower degree of correction than distal to tibial tuberosity.
- Because the patellar tendon may be damaged during the osteotomy or fibrosed after recovery, it is more likely than the distal kind to develop patella infera.
- The narrow proximal tibial segment may predispose to fracture in the tibial plateau while fulcruming on the lateral cortex expands the wedge.
- Because the proximal section is tiny, it is more difficult to secure the utilized plate [23].

***(2) Open wedge osteotomy distal to the tibial tuberosity (OWODT).***

**Technique:** The osteotomy, in this case, is performed below the level of the tibial tuberosity, in a transverse line from the medial cortex, leaving the lateral cortex intact (Figure 2). The bone at the location of the osteotomy is opened, with the fulcrum on the lateral cortex, until alignment is achieved. In this case, the fibula will have a tethering effect and prevent the osteotomy from opening, which can be addressed in a variety of ways [24].

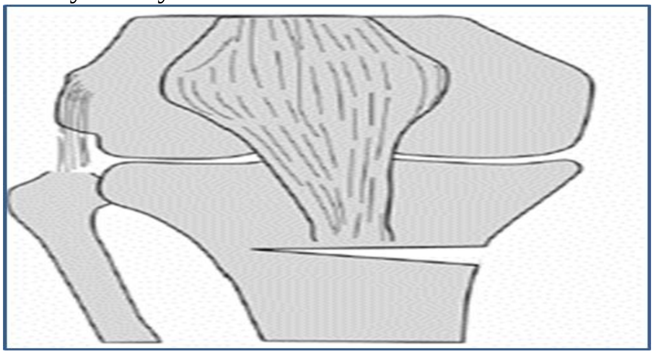

**Figure (2):** Open wedge osteotomy distal to the tibial tuberosity [22]

***Advantage of OWODT:***

- It may be performed on cases with an open growth plate, offering a wider range of corrections.
- Leaving a lengthier proximal portion of the proximal tibia to facilitate fixation.
- Easier to execute.
- Since the osteotomy is carried out below the insertion level of the patellar tendon is unaffected [24].

***The disadvantage of OWODT:***

- Due to the cortical structure of the bone in this part of the tibia, bone healing is slower, with a greater risk of delayed union.
- Fibular osteotomy is required to remove the tethering effect [24].
- Opening wedge osteotomy allows for precise intraoperative angular adjustment, while eliminating the necessity for lateral dissection. The likelihood of peroneal nerve and extensor hallicus longus palsy is reduced in the medial method because no proximal tibia–fibula joint release or resection is required. On the other hand, because of the little bone contact, it is relatively unstable, especially if not fastened. It also leaves a gap between the bone ends, which must be repaired by bone graft [25].

***1. Fixation of the osteotomy site:***

Biocritical bone wedges of adequate size are put within the wedge with no internal fixation or plaster cast, with the wedge kept in place by compressive force in the opening osteotomy. However, the lateral section of the cortex may breakthrough or post the osteotomy, producing displacement and loss of correction. Hence, internal or external fixation is utilized [26].

***2. Internal Fixation:***

Internal fixation is achieved by staples or crossing k-wires or plates and screws.

***3. Plate used in fixation of open wedge osteotomy*** **(**Figure 3):

i. T-shaped plates: It was located on the tibia's anteromedial surface. In order to keep the osteotomy, open until screws are introduced, a bone spreader is implanted. The plate was proximally fixed with three locking head screws, which provided extensive support of the tibial plateau in the subcortical region. After that, the plate was pre-tensioned by inserting a temporary lag screw distal to the osteotomy. This technique approximates the distal fragment to the plate and induces compression on the lateral cortical hinge even when it has been destroyed. Finally, the distal locking head screws were inserted for definitive plate fixation, and the lag screw was replaced with a locking head screw [27].

ii. B. Braun Aesculap plates: Two open-wedged plates can also be used to support the osteotomy. The posterior plate was positioned as far back as feasible on the proximal tibia, near the posteromedial corner. The anterior plate was inserted below the oblique tuberosity osteotomy and was 2 to 4 mm shorter than the posterior plate, depending on the size [28].

iii. Osteotomy plate (puddu plate): It is composed of a body with a front and backside. A protrusion extending from the backside of the body for placement in the wedge-shaped osteotomy that can be configured in a variety of shapes and sizes to fit in the wedge-shaped osteotomy and stabilize the tibia in the desired orientation [29].

iv. Anthony plate: The Anthony-K plate is modular, which means it is made up of two parts. The proximal component consists of a wedge that supports the proximal tibial metaphysis area and is secured to the osteotomy site by two parallel screws. The wedge forms the distal component, which is supported on the distal plane of the osteotomy hole and can be secured with up to three screws. These sections are held together by millimeter-marked teeth that prevent them from slipping against one other. These teeth allow you to change the distance between the wedges [29].

v. Plate with a wedge: Plates feature wedge-shaped triangular portions with a 4-mm depth to support the osteotomy surfaces inside. The rectangle-shaped ones have two or four holes. Reverse L shaped plates with four holes are also utilized for the right and left knees. The heights of the wedges are 5, 6, 7.5, 9, 10, 11, 12.5, and 15 mm. The wedges in four-hole rectangular plates were divided to each side in order to place a graft in between. This feature of the plates allows the creation of bony tissue to continue after the bone union phase in the space between the wedges. Both anteriorly and posteriorly, two 2-hole plates of varying heights were employed [30].

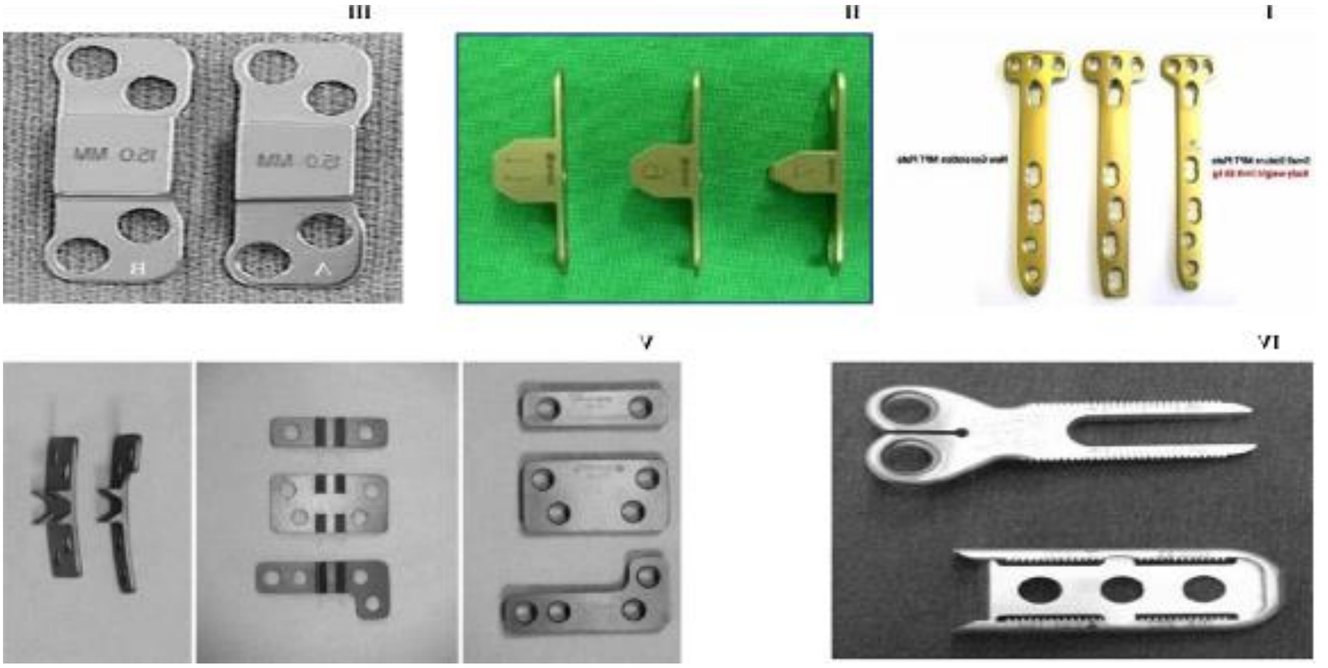


**Figure (3):** Plate used in fixation of open wedge osteotomy, (I) T shaped plates, (II) B. Braun Aesculap plate, (III) The sloped Puddu plate, (IV) Anthony plate, and (V) Plates with wedge [30]**.**

***4. Closing wedge osteotomy:***

A closed wedge osteotomy, on the other hand, will shorten the limb without requiring a transplant (Figure 4). In addition, oblique, dome, and step-cut osteotomies are discussed in chap [12].

- *Closing wedge osteotomy proximal to tibial tuberosity*: It has a high rate of bone healing due to the wide cancellous bone area of contact, but it has a restricted degree of correction [31].
- *Closing wedge osteotomy distal to tibial tuberosity:* It is characterized by delayed bone healing due to the cortical structure of the bone, but it provides a broad range of correction [31].
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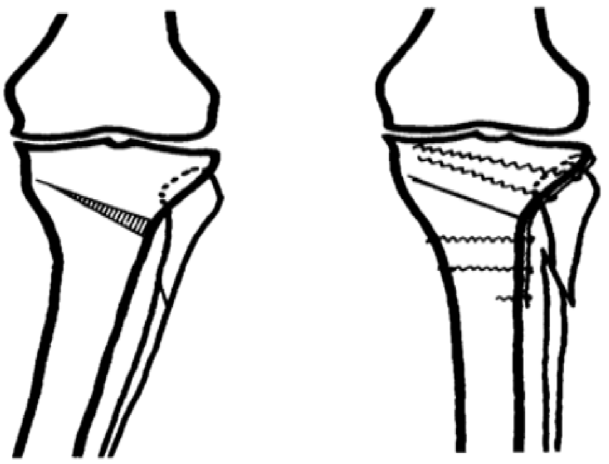

**Figure (4):** Oblique lateral closing wedge metaphyseal osteotomy [32].

**Chevron osteotomy:**

It is an opening-closing chevron osteotomy in infantile tibia vara patients. This osteotomy has the benefit of providing stronger stability and causing the least amount of change in leg length [33].

**W/M osteotomy:**

**Hayek and colleagues** [34] corrected infantile tibia vara by a serrated W/M osteotomy of the proximal tibia. The W/M serrated osteotomy allows for the correction of infantile tibia vara without internal fixation. It enables the complete repair of the deformity while retaining length, restoring joint alignment, and avoiding recurrence.

**Elevation of the depressed medial tibial plateau in tibia vara:**

Many children are not assessed and treated until they have extensive disease-related abnormalities (premature closure of the medial part of the proximal tibial physis with resultant substantial depression of the medial aspect of the tibial articular surface of the tibia). For optimal repair of the distorted anatomy in such individuals, the osteotomy should be paired with an intra-articular elevation of the depressed articular surface of the medial section of the tibia [34].

**Hemi-epiphysiodesis:**

If the growth plates are still open and the varus deformity isn't too severe, hemi-epiphysiodesis by one of many procedures is recommended. There is just no time for correction when a patient is approaching skeletal maturity. A more defective medial physis that is unable to promote corrective growth might explain the increased preoperative deformity. The extraperiosteal positioning of the eight-plate enables simple removal without physeal injury. The eight-plate allows for extraperiosteal implantation and a lateral fulcrum, allowing the remainder of the physis to develop and rectify the angular deformity, although it has a high failure risk in Blount disease (44 %). Stronger implants should be explored in the case of Blount disease [35].

**Postoperative evaluation:**

Clinical examination, clinical scoring, and radiographic assessment using standard radiographs were used for postoperative evaluation at each visit (Plain x-ray Antero-posterior view).

## CONCLUSION

Despite the technological advances and new surgical operation, The treatment of GV deformity in kids is still a serious concern for parents. Various osteotomy techniques have been used, including closing wedge lateral tibial osteotomy, dome osteotomy, and opening wedge medial osteotomy. Autologous fibular strut graft is an excellent, if not superior, graft for open wedge medial tibial osteotomy because of its strength, durability in preserving correction, cost-effectiveness, ease of graft harvest, and restricted incision and pain sites. It is simply accepted by both educated and illiterate parents, as there is no animosity or psychopathology associated with utilizing another person's bone or an artificial substance.

**Conflict of Interest:** There were no possible conflicts of interest revealed by the authors.

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