

An Overview on Treatment of Adolescent Tibiavara

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Abstract:

Adolescent tibiavara differs from infantile Blount's disease in its pathophysiology and prognosis. It typically appears after the age of 10 years and tends to progress rapidly, often requiring surgical correction. Non-surgical approaches are generally ineffective once the deformity is established. Radiographic evaluation using Langenskiöld classification and mechanical axis deviation plays a key role in diagnosis and treatment planning. Surgical intervention, such as proximal tibial osteotomy with or without fibular osteotomy, remains the cornerstone of management. Techniques vary from acute correction with plating to gradual correction using external fixators.

Keywords: Adolescent tibiavara, Blount's disease, Tibial osteotomy, Growth modulation, External fixation, Internal fixation, Limb alignment, Varus deformity, Pediatric orthopedics.

Introduction:

Adolescent tibia vara, also known as late-onset Blount's disease, is a growth disorder of the proximal tibia characterized by progressive varus deformity, internal tibial torsion, and procurvatum. Unlike infantile Blount's disease, the adolescent form presents after the age of 10 years and rarely regresses spontaneously once established (1).

The etiology is multifactorial, with mechanical overload due to obesity playing a key role. Additional factors include abnormal physal growth, genetic predisposition, and ethnic influences that predispose adolescents to disease progression (2).

Conservative management such as bracing is typically ineffective in adolescents because of skeletal maturity. Thus, surgical correction remains the mainstay of treatment, aiming to restore limb alignment, prevent further progression, and reduce the risk of early degenerative changes (3).

Among surgical options, acute corrective osteotomy with internal or external fixation is widely used. A 2021 clinical study reported that minimally invasive osteotomy combined with simple circular frame fixation provided excellent correction in severe cases, with significant improvement in functional scores and no recurrence (4).

For complex or multiplanar deformities, gradual correction using devices such as the Taylor Spatial Frame (TSF) has been shown to be highly effective and reliable. This approach allows precise, controlled adjustments while addressing associated limb length discrepancies, though complications such as pin-site infections remain common (5).

A. Non-operative treatment

Plays no role in adolescent tibia vara (6).

B. Operative treatment

1-Osteotomies:

- I. Acute corrective osteotomy with internal fixation:** Acute correction with internal fixation can correct Tibia vara without risk of physal involvement and bulky external fixator application (7).

Indications

- The CORA is far away from growth plate.
- Deformity in multiple planes, multiapical deformity.
- Deformity presenting in patients near to or after skeletal maturity.
- Diseased physis which can result from trauma and infection.
- Patients with minimal limb length discrepancies allowing correction of the deformity without placing undue stress on the neurovascular structures (less than 20 degree) (7).

Advantages

- Less duration of treatment.
- Can correct multiple planes

Disadvantages

Many complications may occur such as:

- Superficial or deep infections.
- Compartment syndrome.
- Possibility of deep venous thrombosis.
- Injury of physis.
- Injuries to blood vessels.
- Stiffness of the knee joint.
- Delayed or non-union.
- Iatrogenic fractures.
- If the osteotomy fails to heal properly a second surgery may be needed(7).

II. Acute corrective osteotomy with external fixation:

Advantages:

Acute correction with external fixation can correct angular deformity without risk of deep infections and neurovascular compromise(7).

Disadvantages:

- Prolonged duration of treatment.
- Need for frequent follow-up and radiographs.
- Risks of pin infection.
- Fixator malfunction/hardware failure, and potential loss of correction or fracture after fixator removal(7).

2-Gradual correction with external fixation:

Indications:

- Large amount of deformity greater than 30 degree.
- Multiplanar deformities including angulation, translation, rotation, and length.
- Leg length discrepancy.

- The procedure of choice for patients with severe or complex deformities not amenable to acute correction(8).

Advantages:

- Allows for relatively large amount of deformity correction greater than 30 degrees, with little risk of neurovascular compromise and permits concomitant limb lengthening without bone grafting. Also allow to fine tuning the mechanical axis to the desired position in the post-operative period(8).
- Usually requires external fixators which hold corticotomized bone during new bone formation and rotate segments to the desired direction(8).
- Ring fixators are constructed with hinge-motor system which allows for the correction of angular deformity. Versatile placement of hinge on the circular frame offers capability to achieve realignment without creating secondary deformities(8).
- This obviates the need for any bone graft as well as the gap is filled with new bone by the process of distraction osteogenesis.
- The versatile external fixators include the circular Ilizarov fixator **Taylor's** spatial frame (figure1) and the monolateral Rail fixator System (9).



Figure (1): Taylor's spatial frame(9).

Disadvantages

- Prolonged duration of treatment,
- Need for frequent follow-up and radiographs,
- Risks of pin and wire infection,
- Fixator malfunction/hardware failure, and
- Potential loss of correction or fracture after fixator removal. The most common complications include superficial pin infections that respond to oral antibiotics in a majority of patients (8).

3-Guided growth:

Asymmetrical suppression of the physal growth plate using epiphysiodesis, that could be permanent by ablation of one side of the physis or temporary using staple, transphyseal screw, or TBP (8plate)(10).

GUIDED GROWTH:

Relevant Biomechanics:

Heuter first described a scientific explanation for the phenomenon of mechanical manipulation of bone growth in 1862, when he reported that increased pressure parallel to the axis of the epiphysis inhibits growth, while decreased pressure promotes it (10).

After seven years, **Volkman** noted that changes in compressive forces cause asymmetrical growth of a joint. These observations, made almost 150 years ago, laid the foundation for the concept of epiphyseal stapling and have influenced other aspects of pediatric orthopedic practice(10).

Physiological loads stimulate growth, while loads outside this range, either higher or lower, will inhibit it. So that, minor degrees of joint incongruence, where the stresses remain within physiological limits, invoke a negative feedback in order to restore the joint to normal. Increasing incongruency results in the physis being subjected to loads outside the normal physiological range, invoking a positive feedback mechanism which lead to progressive deformity. This complex, non-linear relationship has many implications for the management of deformity, including a window outside which physal manipulation may fail. Most importantly, it suggests that any intervention should be carried out at an early stage when negative feedback correction can be harnessed(11).

Early restoration of the mechanical axis is desirable to avoid permanent abnormality of the adjacent joint surfaces, which will otherwise lead to longterm morbidity (10).

Indications:

- The indications of guided growth for correction of adolescent tibia vara provided the physis has growth potential with minimum 1 year of growth remaining (12).
- However it would seem aggressive to offer this treatment to young children, they tolerate it well, and it is much more preferable to osteotomy, which may have to be repeated. May be the younger the patient, the more resilient the physis is to following temporary growth restraint (13).
- Guided growth technique is applicable for virtually any pathologic condition, including posttraumatic, metabolic, neuromuscular, idiopathic, or congenital disorders. In fact, by restoring the mechanical axis and correcting gait abnormalities (like waddling or circumduction), the physis are spared cumulative damage and may actually respond surprisingly well (14, 15).

Contraindications:

Guided growth technique is contraindicated after skeletal maturity or in the presence of an unresectable physal bar. In the latter situation, while it could prevent progression, it will not provide correction of tibia vara. If a physal bar lends itself to removal, concomitant guided growth may be used to expedite angular correction (12).

Timming of Hemiephysiodesis:

Estimating remaining growth based on skeletal age is an inexact process. The health of the physis must be considered. Several conditions, including skeletal dysplasias, trauma, and irradiation, are associated with abnormal physal growth, and persons with any of these will experience slower correction of angular deformity following hemiephysiodesis. In addition, severe angular deformities may disturb normal physal growth(16).

There is another method for estimating remaining growth by using multiplier application .The multiplier method (MM) is frequently used to predict limb-length discrepancy and timing of epiphyseodesis.

The traditional MM uses complex formulae and requires a calculator. A mobile application was developed in an attempt to simplify and streamline these calculations(6).

Several reports state that the traditional MM is quick and easy to use. Nevertheless, even in the most experienced hands, performing the calculations in clinical practice can be time-consuming(17).

Technique of Guided Growth:

1. Permanent epiphysiodesis:

Direct ablation of one side of the physis, can be done by the Pnemister (open) or percutaneous technique. It's necessarily permanent and used to correct limb malalignment. As those techniques cause permanent arrest of the physis, precise and accurate timing are needed, along with meticulous follow-up (15).

A. Open epiphysiodesis

Pnemister was the first to carry out epiphysiodesis in 1933 and referred to the procedure as 'epiphyseodiaphyseal fusion'. He would excise a rectangular block of cortical bone containing peripheral physis with adjacent metaphyseal and epiphyseal bone, chisel out the growth plate 1 cm deep and then re-insert the excised block in a reversed 180° position, thus to create a bone bridge bypassing the growth plate (figure2) (16).

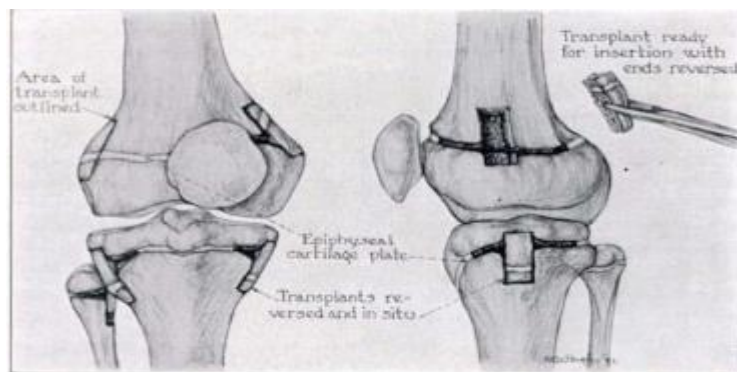


Figure (2): Technique of epiphysiodesis. Transplants reversed and cartilage chiseled out(17) .

B. Percutaneous epiphysiodesis:

With the advent of fluoroscopy in the operating room and the trend toward minimally invasive surgery, new methods have been developed. One such technique, popularized by Bowen in 1984, involved percutaneous ablation of the peripheral aspect of the growth plate with a curette, resulting in physeal closure and permanent growth arrest (17).

C. Transphyseal screws:

In 1998, **Metaizeau et al.**(18) suggested the use of screws across the growth plate to achieve direct compression of the physis. Since the technique was first reported, percutaneous epiphysiodesis using transphyseal screws (PETS) has been used for most of cases using cannulated screws percutaneously under fluoroscopic control (figure3)(18).



Figure (3): Radiograph of the knees taken 8 months after surgery showing the position of the screws across the growth plate (18).

2. Temporary hemiepiphysiodesis (Growth plate modulation) Using Tension Band Plate (8-plate):

Since there is no known effective non operative treatment for substantial degrees of adolescent tibia vara, patients usually undergo surgical treatment. Surgical treatment options of adolescent tibia vara include corrective valgus osteotomy of the proximal part of the tibia and lateral hemiepiphysiodesis of the proximal part of the tibia and/or distal part of the femur(14).

Hemiepiphysiodesis is attractive as a surgical option because it is a less invasive procedure that does not require immobilization or non-weight-bearing in the postoperative period. Reported rates of success of hemiepiphysiodesis for the treatment of adolescent tibia vara have ranged from 50% to 88%(14).

It has been presumed that staples could be left in place for as long as 2 years without causing permanent growth arrest. Although, numerous complications have been observed with staples, including staple failure, breakage, and extrusion(17).

To avoid these complications, Peter M. Stevens devised a new device comprised of two screws and a two-hole plate (Figure 4) and coined the term guided growth to describe its action on the growth plate(19).

The design of the eight- Plate guided growth system is thought to be an improvement over the Blount staple as it theoretically does not compress the growth plate like a staple and it is more resistant to spontaneous extrusion. This is a dynamic construct consisting of a two-hole pre-contoured plate (figure 5), made of stainless steel or titanium, with a choice of two sets of nonlocking 4.5 mm fully threaded, self-tapping screws, cannulated screws which are available in variable lengths(10).

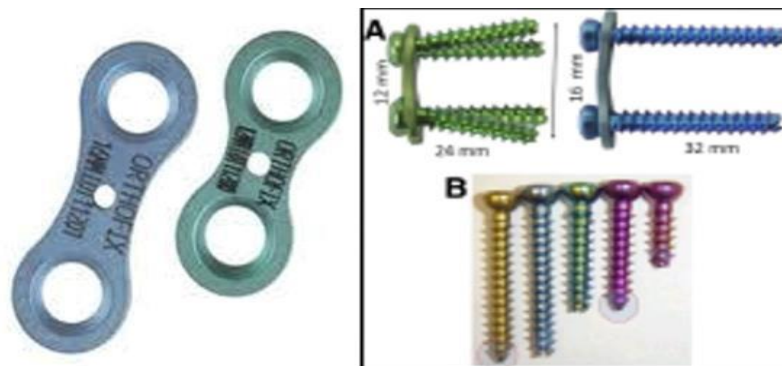


Figure (4): (A) The 8-plates (B) The cannulated screws(19).

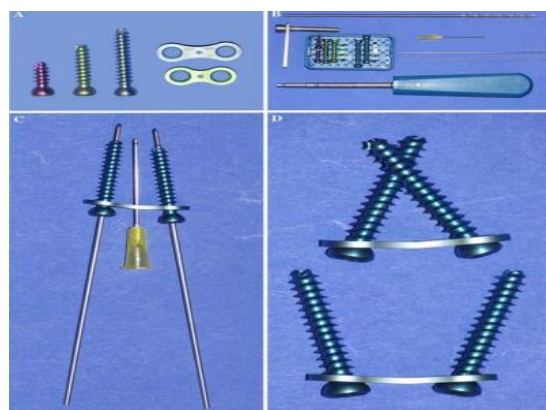


Figure (5): 8-plate guided growth system(19).

Principles of 8-plate:

The 8-plate is designed to act as a 'tension-band' rather than providing the compressive forces associated with a staple. Whilst a staple imposes a rigid fulcrum within the physis, the 8-plate places the centre of rotation

outside it creating a longer moment arm for physal growth, theoretically allowing a more rapid correction while maintaining overall bone length. The ability of the screws to pivot results in lower pressure transmission across the physis, so that reducing the risk of physal fusion. Screws make the construct more resistant to extrusion than the smooth blades of a staple, particularly in younger children in whom the epiphyses are largely cartilaginous(10).

Parallel screws were found to be superior to divergent screws at all time points, and to a lesser extent to hyperdivergent screws. This may be related to the toggle effect. Parallel screws have a greater capacity to toggle with growth at the plate/screw interface. This effectively shifts the center of rotation to a truly extraphyseal position, so that increasing the biomechanical efficiency of the system. In contrast, divergent screws may be relatively more fixed at the plate/screw interface, shifting the center of rotation to a slightly intraphyseal, less advantageous position(20).

The results for hyperdivergent screws are in between the two. One possible explanation for this finding is that these screws diverge to such an extent that the heads are not seated entirely within the plate, and they may therefore have regained some ability to toggle with growth(17).

The eight-Plate is temporary, and its extraperiosteal placement allowing easy removal without physal damage. This decreases the dependence on the imprecise science of estimating the remaining growth and allows children of all ages to be candidates for surgery (21).

Surgical Technique:

This technique is carried out under general or spinal anesthesia and tourniquet control, with the patient positioned supine on a radiolucent table. The physis is localized with the image intensifier in both the frontal and sagittal planes, and a 2.5-cm vertical skin incision is made on lat proximaltibia(physis)(22).

Successive layers of tissue are longitudinally split till reaching the periosteum, which is left intact. A useful rule of thumb is that if the structure can be lifted with forceps, it should be split. The periosteum is tightly adhered to the bone and cannot be lifted with forceps(22).

The epiphyseal vessels are left undisturbed (figure 6). Use a 12-mm eight-Plate for the proximal tibia and a 16-mm eight-Plate for the distal femur. The eight-Plate is suspended off a 20-gauge needle or small-diameter wire through the central guide hole, which is placed therefor it is centered on the growth plate (Figure 6a)(22).

The position of the eightPlate is verified in the anteroposterior and lateral views using the image intensifier, and the eight-Plate is adjusted until the desired position is obtained (Figure 6b). The eight-Plate should straddle the physis in the anteroposterior view and be centered midway in the sagittal plane(10, 12).



Figure (6): Surgical technique of tension band plate (8 plate)(10).

The 1.5-mm temporary guide wires are inserted in both holes of the eight- Plate under image intensifier control to direct them away from the growth plate. Ideally, they should be as parallel as possible. A 3.2-mm cannulated drill bit is then used to ream the outer cortex to a depth of 5 mm over each of the two guide wires (22).

Cannulated screws are inserted and gently tightened to hold the eight-Plate in position and length of cannulated screw must not exceed midline of growth plate. Before final tightening, the soft tissue is carefully examined to ensure that the mobile structures like the fascia are not trapped under the eight-Plate. The guide wires are removed. Final radiographs in the anteroposterior and lateral views are attained with an image intensifier. The tourniquet is removed, hemostasis is obtained with electrocautery, and a solution of 0.5% bupivacaine with epinephrine is injected into the wound edges. The incision is closed in layers with absorbable suture and subcuticular skin closure. A Tegaderm transparent dressing and a light compressive dressing are applied. A bag of ice or other cold delivery system can be intermittently applied to prevent swelling, especially for distal femoral application (figure 7)(22).

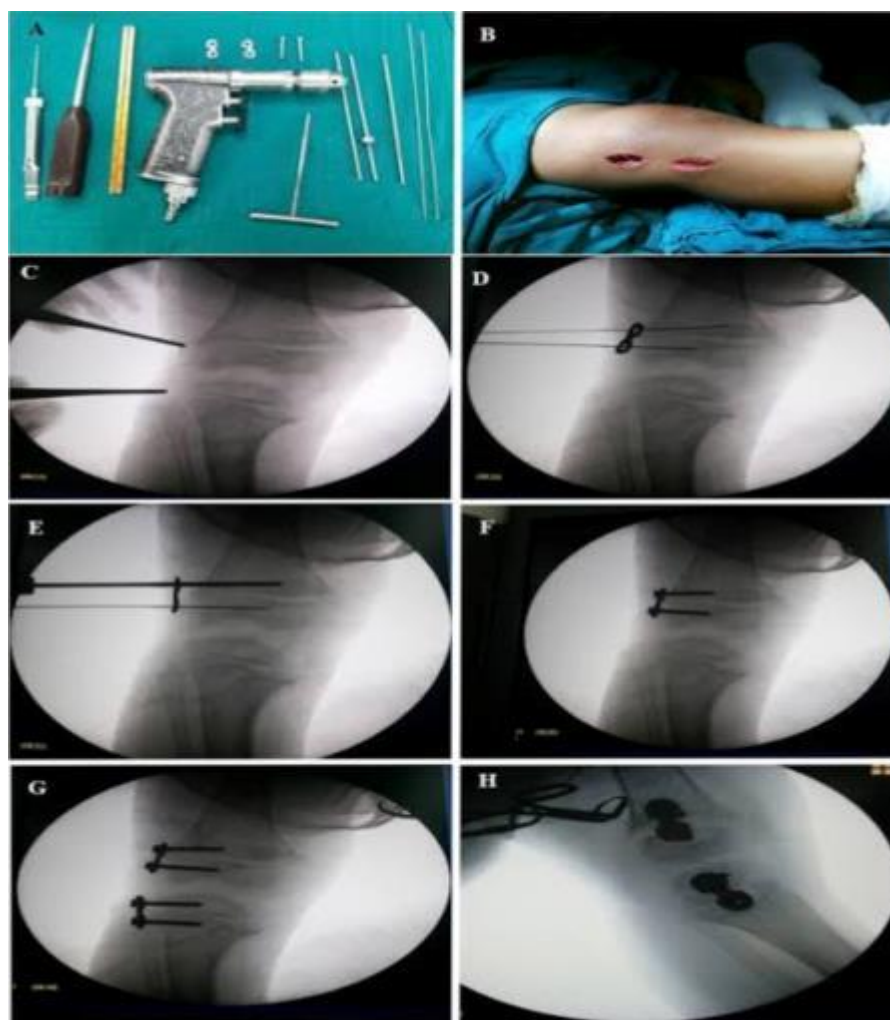


Figure (7): Application of the eight- Plate(22).

Post-operative management:

The patient can be discharged to home or spend a night in the hospital, according to pain management requirements and the social situation, Crutches are optional and can be used for 3–7 days, after which progressive activities are permitted as tolerated(22) .

Physiotherapy is prescribed only if the child is not bending the knee well during the first follow-up visit (7-14 days after surgery) when the wound is examined. Physiotherapy is more likely to be required after femoral

rather than tibial applications, as there might be a knee hemarthrosis. Return to full activity, including contact sports, is allowed 4 weeks following surgery(22).

Patients should be seen at intervals of 3 months, to monitor growth and deformity correction(22).

As the correction occurs, the screws diverge or pivot (figure 8). Erect limb radiographs are attained and measured to determine the change in the joint orientation angles and the mechanical axis of the limb. A slight over correction of the mechanical axis might be recommended because some rebound growth can occur after eight-Plate removal(22).



Figure (8): Photograph showing an 8-plate demonstrating how the screws pivot in the plate in response to physal growth(10).

The removal is carried out under general or spinal anesthesia and under tourniquet control. The scar is sharply divided and can be excised if needed. In the most cases, the eight-Plate is easily found after dissecting the subcutaneous and deep tissues. Although, it's recommended that an image intensifier is available in case the surgeon experiences any difficulty locating the eight-Plate(10).

It is very important to preserve the integrity of the periosteum and the perichondrial ring to decrease the risk of physal bar formation. Return to full activity, including contact sports, is allowed within 4 weeks after eight-Plate removal. After removal, the patient should attend regular follow-up visits till skeletal maturity. During follow-up visits, standing full length AP radiographs are attained so that the surgeon can monitor for recurrence of the original deformity. If recurrence is experienced, the eight-Plate can be reinserted again(22).

Complications of Guided Growth:

Complications associated with guided growth can be classified as:

1. Infection
2. Swelling
3. Stiffness
4. Hardware-related (eg, implant extrusion, breakage, prominence)
5. Growth-related (eg, undercorrection, overcorrection, permanent physal injury).
6. Hemarthrosis and knee effusion have been reported in some cases; these conditions tend to resolve by 3 weeks. The infections tend to be superficial and resolve with oral antibiotics. Growth related complications, such as undercorrection and overcorrection, can be decreased with close follow-up.
7. Permanent physal arrest has become uncommon in this era of extraperiosteal placement of temporary hemiephysiodesis devices and with special attention paid at the time of implant removal (23).

8. Failure of tension band plate

In **Burghardt et al.**(24) study, there was 65 reported cases of mechanical failure, it was the eight-Plate screws, and not the plate itself, that failed. The plate is solid titanium; however, the screws are cannulated and have a smaller cross section, making them the weakest part of the implant.

Fractures occur almost always in the metaphyseal screw, not where the head meets the shank but where the shank enters the lateral cortex, presumably due to 3-point bending, **Stevens** believes that if the plate is not coapted to the bone by alternately tightening the 2 screws (as one might alternately tighten lug nuts on an automobile wheel), then the exposed portion of the distal screw is at risk. The same risk may compromise larger or solid screws. Proper tightening technique might prevent this problem. Stevens also reported that he has never personally had to contour (bend) an eight-Plate (12).

Park et al.(25) reported that body weight is likely a crucial factor in breakage in cases of Blount disease, there might be an unrecognized rotational instability of the epiphysis in relation to the metaphysis (similar to slipped capital femoral epiphysis) that places the hardware under additional stress. In one case, a 12 years old boy with severe Blount disease and obesity (BMI of 36.4 kg/m²) experienced failure of both screws (epiphyseal and metaphyseal screws) in the lateral proximal tibia (Figure 9) (25,26).



Figure (9): Radiograph shows patient with broken metaphyseal screw. Note the distal drifting of the screw tip as evidence of continuing growth (26).

Other devices used for temporary hemi-epiphysiodesis:

Two potential alternatives include using two 2 parallel eight-Plates in either a parallel or oblique fashion (Figure 10) or using solid screws that are 70% stronger than cannulated screws. Bending the plate before insertion to conform to the bone surface is another strategy to ensure good bony contact. If these guidelines are followed when patients are overweight or obese, the likelihood of experiencing eight-Plate failure would be greatly reduced (26).

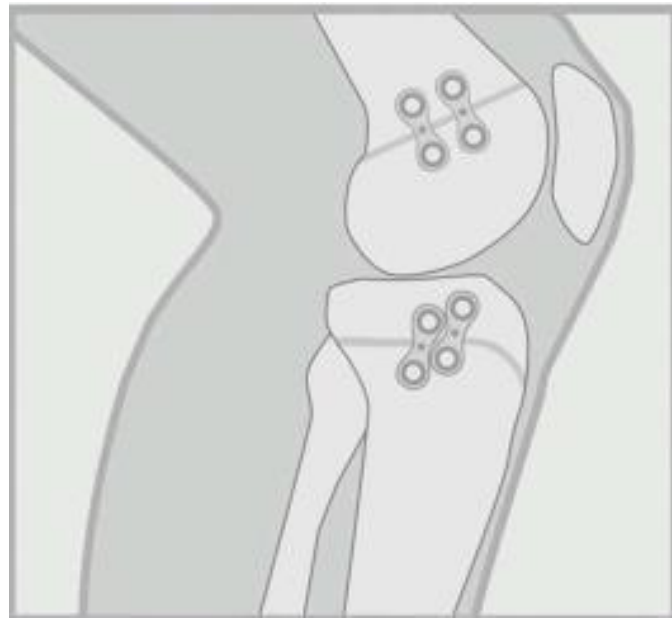


Figure (10): Proposed position of 2 eight-Plates nested obliquely in the tibia and inserted parallel in the femur. This may be an alternative in obese patients or those with severe deformities (27).

In 2013 **Böhm** and **Tung-Yi Lin**, published two papers in which they documented the use of a two-hole one-third tubular plate when the medical insurance does not cover the high cost of the titanium 8- plate in guided growth. The original design of stainless-steel plates includes 2–12 holes, with 1.0mm thickness and 9.0mm width (28). (Figure 11)

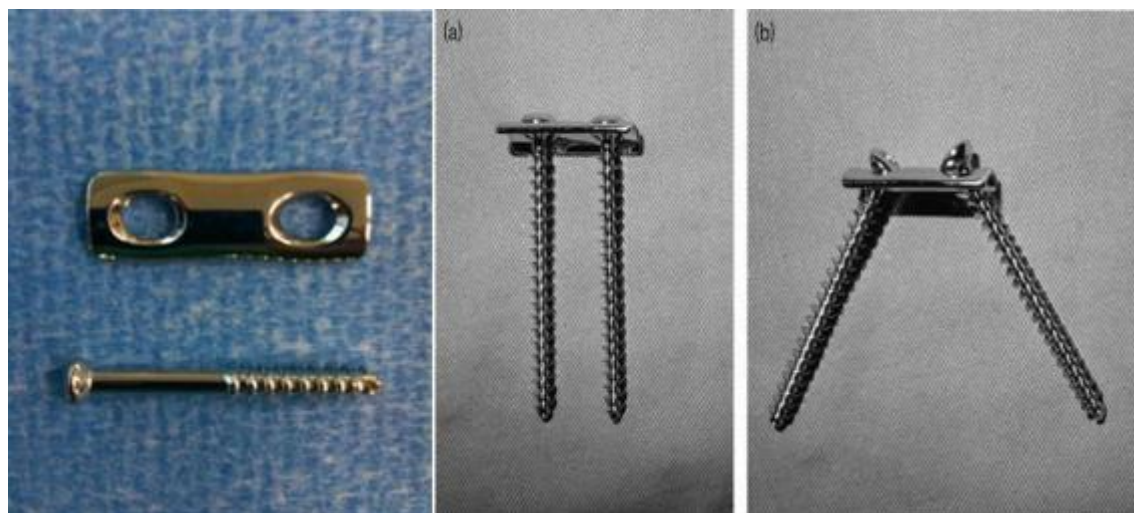


Figure (11): 2-hole 1/3 tubular p2-hole (28).

In 2015 **Wu et al.** published an animal study in which he compared the correction power of a newly designed H-plate and the conventional 8-plate in pigs. H-plate was designed just like the conventional 8-plate with a hinge between the two holes of the plate and works on the same concept as the eightplate (Figure 12) (29).

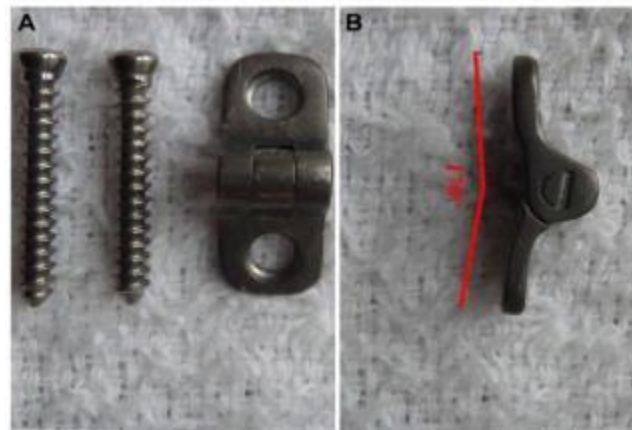


Figure (12): H-plate (29).

In 2018 **Kadhim et al.** compared the correction power of H-plate and 8-plate in children and he found that there is no difference as both plate systems have the same correction rate in the distal femur and the proximal tibia in children(30).

In 2017 **Martínez et al.** proposed a new system as an alternative to the 8-plate composed of two screws and a nonabsorbable filament in correction of genu valgum deformity in the distal femur. He stated that it is an effective and safe method for correction of mechanical axis deviation in pediatric patients. And is a cheap alternative to the 8-plate (Figure 13) (31).

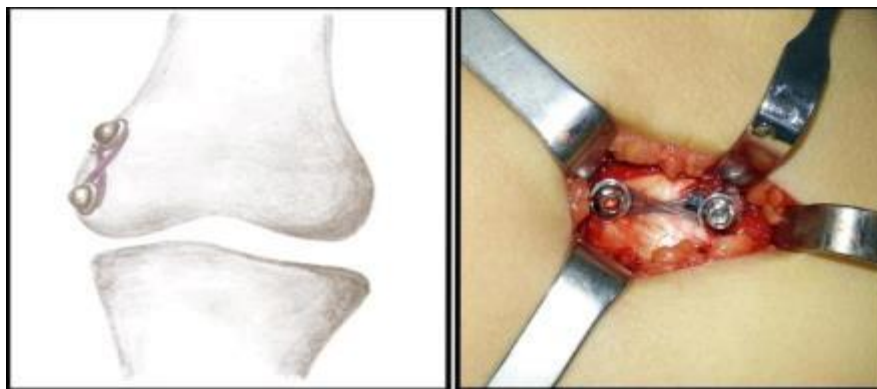


Figure (13): Scheme of hemiepiphysiodesis with screws and non-absorbable filament (31).

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