

Managing coronal plane deformities around the knee by Using percutaneous osteotomy

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Abstract

Coronal plane deformities around the knee, encompassing genu varum and genu valgum, present significant challenges in pediatric and adult orthopedics. While various surgical techniques exist, percutaneous osteotomy offers a minimally invasive approach with potential advantages in reducing morbidity and improving functional outcomes. These abstract reviews the current literature on percutaneous osteotomy for managing these deformities, highlighting its techniques, indications, and limitations. Percutaneous osteotomy utilizes small incisions and specialized instruments to perform osteotomies, minimizing soft tissue trauma compared to open techniques. Several techniques exist, including closing wedge, opening wedge, and oblique osteotomies, each tailored to the specific deformity and patient characteristics. The choice of osteotomy type depends on the desired correction, bone morphology, and the presence of concomitant deformities. Precise preoperative planning, often employing three-dimensional imaging and computer-assisted surgical navigation, is crucial to achieve accurate correction. The indications for percutaneous osteotomy in managing coronal plane deformities vary based on factors such as patient age, skeletal maturity, deformity severity, and associated comorbidities. It is particularly attractive in skeletally immature patients where growth modulation techniques may be insufficient or contraindicated. In adults, percutaneous osteotomy can effectively address mild-to-moderate deformities, improving joint mechanics and reducing pain. However, severe deformities or those with significant bone loss or malunion may require more extensive open surgical approaches. Postoperative management typically involves immobilization with a cast or brace, followed by a gradual return to weight-bearing activities. Regular radiographic follow-up is essential to monitor healing and assess the stability of the osteotomy. While percutaneous osteotomy offers a minimally invasive advantage, potential complications include non-union, malunion, infection, and neurovascular injury. However, the risk of these complications is generally lower compared to open techniques. Studies comparing percutaneous osteotomy to open techniques have shown comparable rates of correction and functional outcomes in select patient populations. Minimally invasive techniques lead to reduced blood loss, shorter hospital stays, faster rehabilitation, and improved cosmetic results. However, the learning curve for

percutaneous osteotomy is steeper, requiring specialized training and experience. Further research is needed to optimize surgical techniques, refine patient selection criteria, and further evaluate the long-term outcomes of percutaneous osteotomy in managing coronal plane deformities around the knee. In conclusion, percutaneous osteotomy presents a viable and increasingly popular alternative for the management of select coronal plane deformities around the knee, offering a balance between minimally invasive surgery and effective deformity correction.

Keywords: coronal plane deformities, percutaneous osteotomy

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Introduction

The aim of limb reconstruction and deformity correction surgeries is to improve final functional outcome of the limb and the patient as a whole, restoring normal joint orientation and limb alignment, equalize limb lengths at skeletal maturity, and prevent recurrence. the approach must be tailored to the patient deformity profile , as Lower limb deformities can widely vary regarding etiology, magnitude, state of soft-tissue coverage , natural history, mode of correction, type , level of osteotomy and of method of fixation. Therefore Choosing the best suited clinical approach for each patient depends on the following factors [1].

The surgeon.

Deformity correction using any technique requires certain experience. Although the correction using Ilizarov principles usually involves simple osteotomy type and a simple frame assembly , however the details of every step are exacting. [2].

The patient and their family should be informed about every step in their management plan . The external fixation apparatus is visible and can not be ignored easily.therefore Some parents may prefer internal fixation . Also the parents should be informed about the postoperative protocols of multiple visits [2].

The bone: Bone healing and length are considered opposing situations.in cases of opening wedge osteotomy there is a risks non-union while a closing wedge leads to shortening.The Ilizarov technique can manage both of these considerations by gradual distraction. [3].

Also Bone quality can affect the choice of fixation. As Patients with poor bone quality making internal fixation with a plate a poor option while Intramedullary fixation or locked plate will be more reliable. [4].

The soft tissue: soft tissue condition will affect the surgical approach used as if there any scarring, or infection then external fixation will be better option rather than internal fixation

common peroneal nerve is at risk during acute correction from valgus to varus and external to internal torsion at the level of proximal tibia as opening wedge osteotomy will lead to lengthening, tissues at the concave side may be at risk specially if there is a skin tethering by old scar tissue [5].

Indications for surgical correction:

The decision about whether or not to correct a specific deformity can be quite different from patient to another [6].

General indications

correction of coronal plane deformities around the knee is indicated when:

- (1) if The MA falls within zone 2 and the patient is symptomatic or beyond zone 2 even if the patient is a symptomatic [7]
- (2) deviation more than 5 degrees of the normal joint orientation angles like the lateral distal femur angle (LDFA), the medial proximal tibial angle (MPTA), and the joint line congruency angle (JLCA) from the reference values [8].

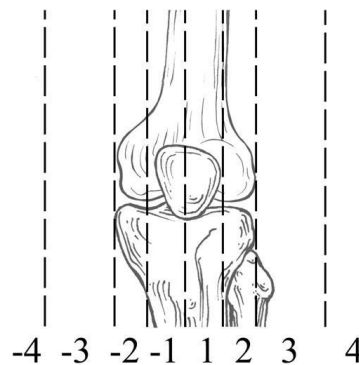


Diagram showing zones of mechanical axis deviation. Zone 1 is within the tibial spine. Zone 2 within the tibial condyles. Zone 3 is within the knee joint width away from the center of the knee joint. Zone 4 is greater than one knee joint width from center of knee joint [9]

Relative Contraindications :

Contraindications are often vague and mostly related to the patient like unrealistic expectations from the operation , inability of the patient to follow the postoperative protocol. [10].

Non operative management Observation:

Specially in young age children with no clear clinical or radiographic findings suggesting pathological deformity , a short trial of observation is given . [11].

Bracing

Bracing is indicated for ITV children below the age 3 years of (I or II) Birch indication criteria for bracing include ,patients aged 3 years old with progressive varus malalignment , ITV of stage (I or II) , or lateral thrust gait [15]. Some Authors like Loder and Johnson reported 50% brace failure due to poor compliance and obesity [1,48,49,50]. The locked KAFO counteracts the medial compressive stresses, allowing for resumption of normal medial growth [12] in stages III or higher bracing is ineffective and delays surgery.



Photograph showing lower extremity brace . [13].

Different surgical modalities:

Soft-Tissue Modification

Soft tissue interventions can be effective either as a solitary procedure or in conjunction with bony surgery. Modification of the soft tissues can be done by addressing the soft tissues themselves like plication of LCL or using bony procedure like distal mobilization of head of fibula to tighten the laxity of LCL [14].

Growth modulation :

Principles

Guided growth Or Hemi epiphysiodesis, can correct angular deformity at the physis based on Hueter–Volkman principal, as compressive forces across a physis inhibit growth, while tensile forces across stimulate growth [15].

indications

1- Skeletally immature patients with sufficient remaining growth potential of minimum 2 years (< 14 years old), 2- the CORA is at or near to the physis, 3- BMI <40 kg/m², 4- body weight < 100 kg. Mackintosh reported that age greater than 14 years, BMI > 45 kg/m², are associated with high failure rate [10]. Stevens stated that guided growth can be used in abnormal physis [16] such as hypophosphatemic rickets

Techniques:

using staples or tension band plate placed extraperiosteal over the convex aspect of deformity either for varus or valgus malalignment .guided growth considered reversible technique as growth will resume after hardware removal [17].

Staples: Haas reported a reversible epiphysiodesis technique using wires over the physis. However, this procedure became more popular after the results of Blount and Clarke[39], who reported Satisfactory results about 80%-85% correction of cases. Implant failure with staple breakage found in 10% of cases [19].

Tension band plate (8 plate): Stevens[40] coined the term “guided growth” and provided an alternate implant of a small, non-rigid extra periosteal plate locked by two screws proximal and distal to the physis acting as a focal hinge at the physis [20].

The critical difference between staples and Stevens’ plate is that the staple is rigid and compresses the physis, while the plate is non-rigid , acting as a tension band plate (TBP)[21]. with a lower risk implant extrusion or breakage. There is some debate about the angle of screws insertion, Eltayeb *et al*[21] reported that the initial screw angle (0-30 degrees) did not significantly affect the rate of correction, however careful screw insertion is essential to avoid physeal injury [21].

Some authors reported a modified technique called the “sleeper plate”[22]. After deformity correction the metaphyseal screw is removed and the plate with the epiphyseal screw is left in place. If deformity reoccurred , the metaphyseal screw is reinserted. Some authors reported a high failure rate with small diameter titanium screws specially in obese patients therefore use solid screws is recommended [23].

Complications:

Some authors reported a success rate of growth modulation up to 100% specially in idiopathic cases [24]. While cases with underlying Pathological etiology have a slightly lower success rate [24].

Complications include:

- (1) Failure of realignment :failure of correction may be related to significant obesity, no much remaining growth potential or underlying physeal pathology "bar"
- (2) Overcorrection:usually due poor patient compliance and failure to attend regular follow up visits

- (3) hardware failure: breakage, migration or extrusion related to using of staples rather than 8-plate
- (4) Premature physal closure: rare complication as long as the plate is removed within 2 or 3 years of insertion To avoid this complication, the whole procedure should be extra periosteal preserving the perichondrial ring of La Croix. This complication is reported be higher in cases of the sleeper plate technique [22].
- (5) Recurrence of deformity: a recurrence of angulation more than 5 degrees of varus or valgus after complete correction usually caused by growth acceleration on the previously tethered growth plate [23].

Leveille *et al*[24] reported a high risk of recurrence of deformity with patients of severe initial deformity (> 20 degrees) early intervention (< 10 years for females and < 12 years for males).

Some authors recommend an overcorrection of 5 degrees[24]. However, Leveille *et al* [25] recommend only over correcting patients of high risk of recurrence , to avoid creating another deformity in patients who do not experience a recurrence.



Scanogram showing a child with ITV with bilateral lateral hemi-epiphysiodesis

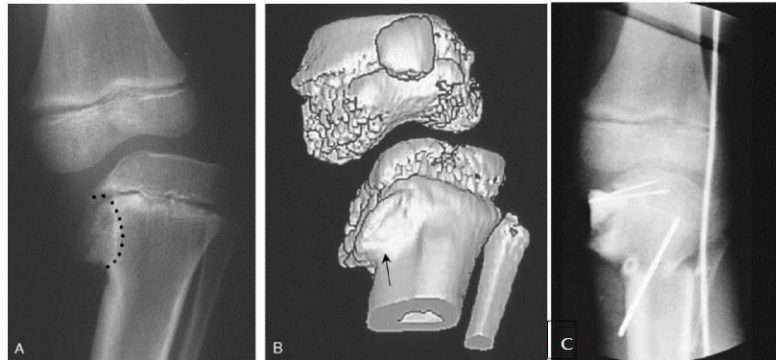
Permanent hemi-epiphysiodesis:

Phemister [26] reported an open technique for surgical closure of the physal plate. In 1993 Terry Canale [27] reported a percutaneous technique of mechanical ablation of the physal plate using a drills and curettes .In 1998 Métaizeau *et al* [31] reported a percutaneous technique using transphysal screws (PETS) using fully threaded cannulated screws producing compression on both sides of physis, The screw is introduced into the metaphysis, crossing the physis and into the epiphysis of the opposite side.

although PETS can be referred to as reversible technique after screw removal, some authors reported physal closure quite quickly after screw insertion and that technique is not reliably reversible as Inadequate timing of surgery could lead to under- or overcorrection of the deformity [28].

Epiphysiolsis :

Physeal bar formation can occur either post traumatic or as a developmental arrest like in blount disease. resection can be done when the bar involves less than 50 % of the physeal width with more than 2 years of remaining growth potential .Andrade reported >80% succession in growth resumption and preventing recurrence in ITV children below the age of 7 years). The major Disadvantages of physeal bar resection include a high failure rate , risk of complete physeal closure and significant angular malalignment can not be corrected with bar resection alone [26].



Xray and CT image showing stage IV ITV the metaphyseal bone and Blount lesion to be excised is outlined; (B) 3D CT showing extent of abnormal depressed epiphyseal bone anteriorly. The "cleft" on the anterior of the metaphysis (arrow) is where the initial resection for epiphysiolsis begins. (C) After interposition of cranioplast at the site of resection and stabilization of a closing wedge tibial osteotomy. [28].

Asymmetrical Physeal Distraction

Physeal distraction was first described by Ring in 1958. Further clinical studies was conducted by Ilizarov in 1969. Spinelli in 1980 stimulated by his visit to Ilizarov and through his own independent work first published this clinical technique In the West under the term of "distraction epiphyseolysis [29].

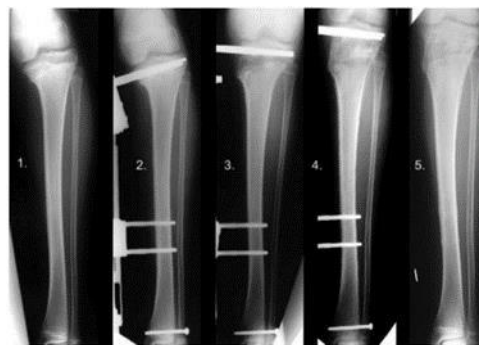
Distraction epiphysiolsis requires gradual distraction of the physeal plate using a circular fixator, Leading to a sudden rupture of the growth plate 3-4 days after this procedure. with marked diastasis at the physeal plate and sudden pain. This is very traumatic to the child and leads to premature physeal closure , therefore Ilizarov has completely abandoned this technique for these reasons although Spinelli still uses it. [30].

Ilizarov has modified this technique with the addition of an extra pre stressed wires " dampers wires" proximally and distally to have a dampening effect to resist any diastasis occur at the time of epiphyseolysis . This leads to less pain and less trauma to the physeal plate. This technique is usually

reserved for adolescent cases so that premature closure of a growth plate would be less problematic [31].

Another modification used by Ilizarov through introducing a K-wire across the plane of the physal plate at its metaphyseal border and fixing it to the frame then . Gentle torsion of the proximal and distal rings of the frame leads to fracture of the growth plate occur at its metaphyseal end like a type 1 Salter Harris fracture through the zone of provisional calcification.

However this technique " chondrodiatasis" is associated with higher complication rate like angulation due to asymmetrical physal distraction , knee joint subluxation and premature physal consolidation .As the complication rate of corticotomy is lower, it appears that correction through corticotomy is more logical to use than physal distraction [32].



Xray image showing Physal distraction in LOTV. X-ray series of a case of LOTV gradually corrected by means of physal distraction: (1) Pre-operative, (2) immediate post-operative, (3) 22 days post-operative angular correction completed, (4) 2 months post-operative after 2.5 cm lengthening to compensate a discrepancy, (5) 4 months post-operative consolidation obtained 96

correction via osteotomy

Acute Correction with internal / external fixation:

Realignment of Angular deformities of mild to moderate severity can be done acutely and stabilized with internal or external fixation. Fixation options range from simple casting, pins plaster technique , internal fixation with plate and screws, to external fixation. Generally, osteotomy with acute correction is indicated when a rapid complete realignment is indicated or when it is preferable not to operate on the physis [34].

The choice of the implant depends on the patient's age, weight, and mobility. However Corrective osteotomy with acute correction mode is usually combined with internal fixation that may be more tolerated by the patient than other fixation methods .The choice of implants depends on the site of the osteotomy [35]. As Intramedullary nails fits well for diaphyseal deformities, juxta articular osteotomies usually fixed by plates.

Acute deformity correction and stabilization using external fixator device provides stable fixation that can allow full weight bearing in the early postoperative period . However acute correction can be complicated by Common peroneal Nerve injury in the form of a transient paralysis of the extensor hallucis longus specially during acute correction of proximal tibia valgus deformity. Also during severe varus correction , because of medial displacement of proximal fragment lead to traction and compression of the peroneal nerve , therefore prophylactic peroneal nerve decompression can be done to avoid such complication .21. Other complications include compartmental syndrome, residual deformity, limb-length discrepancy ,delayed union and implant failure [36].

Disadvantages acute correction with internal fixation are the relatively larger amount of soft tissue dissection needed for exposure for plate insertion , lack of ability to fine tune the deformity postoperatively, and the complications associated with poor skin condition. [37].



Radiographs showing a case of bilateral genu valgum with CORA in distal femur. b. Radiographs of the same child after bilateral corrective osteotomy [37].

The fixator assisted internal fixation

Accurate precise acute correction can be achieved using a temporary external fixator to achieve correction, assessment of accuracy on operating table and intraoperative adjustments if needed, Then followed by internal fixation ,finally removal of the fixator [37].

Hemi-Plateau Elevation Osteotomy

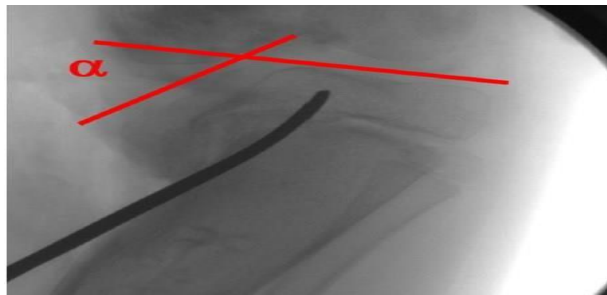
Depression of the medial tibial plateau usually present in Late cases of ITV The deformity appear worse on radiology than it actually is due to the presence of unossified cartilaginous part [15] therefore MRI and intra-operative arthrography can be useful to delineate the exact articular congruity . Langenskiöld and Riska recommended hemi-plateau elevation osteotomy for late presenting ITV

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in 1964, however Stanitski et al. reported that the “empty” space seen x-ray had unossified cartilaginous material [40].

The medial plateau depression angle is measured. The depression can be elevated with an oblique osteotomy starting in the axilla of the metaphyseal beak into the intercondylar area. Barka et al. described the “inside-out” technique in order to avoid articular fracture and medial tibial condyle displacement. Then defect is grafted, and the osteotomy stabilized with either internal or external fixation. This osteotomy is usually performed in combination with additional procedures like metaphyseal osteotomy to acutely or gradually correct residual deformities. [39].



Radiographic image The medial tibial plateau depression angle (α) between a tangent to the lateral plateau and medial plateau



Radiographic image showing The osteotomy is complete with iliac crest allograft is impacted in the opening wedge



Radiographic image showing . The osteotomy and allograft are stabilized with screws; the proximal is completed by placing a lateral tension band to prevent recurrence

combined double level Osteotomies

Many authors reported good results performing combined osteotomies specially in case of late presenting ITV including acute elevation of the medial plateau, metaphyseal osteotomy of the tibia . [40].

Gradual Correction with External Fixation of different designs

Percutaneous osteotomy with gradual correction mode using External fixation is a powerful tool for treating complex lower extremity deformities. It allows for precise deformity correction with minimal soft tissue dissection. Gradual correction using external fixators minimize the risk of neurovascular complications with the ability to fine tune the deformity to gain precise correction

Gradual correction can be achieved by monolateral external fixators, circular external fixators or self-lengthening nails that have the advantages of gradual correction with internal fixation although they lack the ability to correct angular deviation as they depend on acute angular correction then gradual lengthening . [41].

Although gradual correction have many advantages like minimal soft- tissue dissection, early weight bearing , can deal with problems that arise during the postoperative period, however it requires high patient compliance and adherence to postoperative protocol [42].

Many designs of external fixators have been developed for deformity correction and lengthening. The Ilizarov frame is well known for its use in deformity correction [1, 8, 24]. Ilizarov frame Can correct any plane deviation in a step- by-step fashion. Angulation can be corrected using hinges, translation using a translation mechanism, rotation using a rotation mechanism and lengthening using threaded rods [43].

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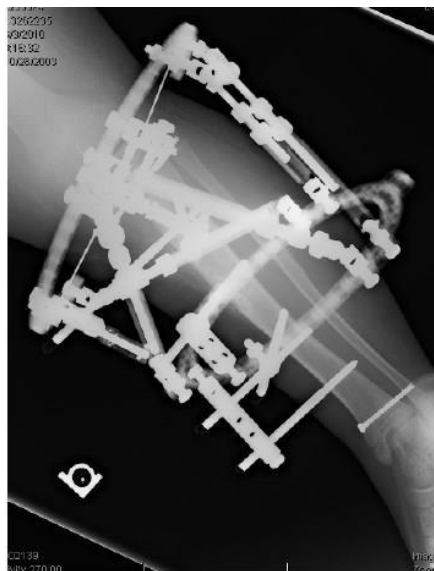
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Deformity correction using ilizarov frame requires frequent modification of the external frame changing the correction constructs This is time consuming and technically demanding specially for multiapical deformities as the psychosocial impact of the bulk of the frame and cosmetic appearance of pin can alter patient metal health [44].

Besides Inadequate frame assembly leads to secondary deformity,that requires additional frame modifications increasing the external fixation time [44].

There are many designs of external fixators available, which generally could be classified into two types, ring and unilateral fixators.⁵ Both have the needed mechanical stability for controlled distraction histogenesis.^{6,7} However, unilateral fixators have limited role in angular deformity as they lack hinge system. Some modified unilateral fixators are designed to include hinge system, however accurate realignment is difficult due to limited versatility of hinge placement.⁸ on the contrary Ring fixators are designed to include hinge-motor system which allows for accurate angular deformity correction . Versatile placement of hinge on the frame provides realignment without creating secondary deformities. [43].

The Taylor spatial frame (TSF) fixator was invented by Dr. J. Charles Taylor in 1994 who designed the frame, adhering to Ilizarov principles , to overcome the drawbacks of the classic Ilizarov frame. This system composes of six telescopic struts attached to two rings and a computer software. TSF can correct a deformity independent of magnitude, complexity, or location. [44].



Radiographic image showing a hexapod was placed to correct tibia varus, internal torsion, procurvatum and 3 cm of length was gained due to the growth plate closures

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