Biological Bone Plate and Iliac Bone Autograft for Proximal Tibial Slope Changing Osteotomy in Genu Recurvatum

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Abstract: Genu recurvatum (GR) is defined as knee hyperextension greater than 5°, with the normal physiological accepted limits of up to 10 to 15° of extension. Physiological GR is commonly bilateral, symmetrical, and mostly asymptomatic. Pathologic GR is usually asymmetric, symptomatic, and can be congenital or acquired. Acquired GR can be classified according to the origin of the deformity into pure osseous, soft tissue, and combined types. Symptomatic GR can present with anterior knee pain and/or instability. Surgery is generally indicated in symptomatic (pain, instability), pathologic GR with an associated causative correctible deformity (bony, soft tissue, or a combination of both). Tibial slope—reversing osteotomy is indicated for the osseous or mixed types where there is inverted tibial slope. Varu-correcting osteotomy is indicated in the posttraumatic soft-tissue type (posterior and lateral soft-tissue injury as in knee dislocation), the aim of osteotomy is to protect the reconstructed ligaments. No role for osteotomy in the nontraumatic soft tissue type (gradual stretching of the posterior structures). In this article, we describe a technique to correct a unilateral genu recurvatum deformity with inverted tibial slope, mostly due to Osgood-Schlatter disease. Correction is done by performing an anterior open-wedge osteotomy of the proximal tibia and impaction of 2 wedges of autogenous iliac bone grafts within the osteotomy. The proximal portion of the tibia is cut in the coronal plan and is used as a biologic plate for fixation with no need for additional hardware (e.g., plate or staples) for fixation of the osteotomy.

Genu recurvatum (GR) is a knee hyperextension deformity. From Latin, genu: knee and recurvare: to bend back. GR is operationally defined as a knee extension greater than 5°. Although there is no consensus about the limits of “normality” of knee joint extension, Murphey et al. suggest that a knee joint range of motion including 10° to 15° of extension is considered normal, and a knee with more than 15° of extension is considered as “pathologic.” Constitutional “physiological” knee hyperextension of up to 15° has been found to fluctuate from 10% to 25% between Eastern populations and others and is commonly bilateral, symmetrical, and mostly asymptomatic. Pathologic GR is usually asymmetric and can be congenital or acquired. Acquired GR has been classified by Dejour et al. according to the origin into 3 patterns: (1) pure osseous deformity due to tibial tubercle (TT) growth plate damage resulting in inversion of the tibial slope in the sagittal plane. Growth plate damage may result from direct trauma, fractures, osteomyelitis, Osgood-Schlatter disease, or radiotherapy. (2) Soft tissue related. This pattern may be due to trauma or chronic tissue stretching. (3) A mixed type resulting from a combination of both osseous and soft tissue disorders as in poliomyelitis. Moroni et al. described a fourth idiopathic type when the cause is unknown, the clinical presentation of which was symptomatic, bilateral, and symmetrical GR >15°. Idiopathic GR is considered pathologic. Treatment of symptomatic GR can be directed toward the pathologic origin of the condition. Osseous GR can be managed by tibial osteotomy. Soft-tissue GR can be managed by
Table 1. Surgical Steps, Pearls, and Pitfalls of the Technique

| Surgical steps                  | Pearls                                      | Pitfalls                                                                 |
|----------------------------------|---------------------------------------------|--------------------------------------------------------------------------|
| Skin incision                    | Make it just lateral to the tibial crest.   | Direct incision on the tibial shin may jeopardize wound healing.         |
| Proximal tibial exposure         | Ensure subperiosteal exposure.              | Nonmeticulous subperiosteal exposure or using sharp Hohmann retractors will damage the muscles of the anterior compartment or the neurovascular structures. |
|                                  | Use blunt Hohmann retractors.               |                                                                          |
| Osteotomy of the proximal tibia. | Localize the site of cutting with an        | If not well localized, this will result in a superficial cut that may easily breaks or an undesired deep cut. |
|                                  | electrocautery.                             | Blunt saw blade increases the operative time and increases the incidence of bone necrosis and infection. |
|                                  | Use a sharp saw blade.                      | No irrigation will increase the incidence of thermal bone necrosis and infection. |
|                                  | Continually irrigate with saline while      | Leaving it exposed will cause it to dry out and become exposed to infection or fracture |
|                                  | cutting with the saw.                       |                                                                          |
|                                  | Wrap the cut fragment with a wet towel and  |                                                                          |
|                                  | protect it.                                 |                                                                          |
| Insertion of K-wires for the     | Under image control.                        | If not done under image control, it will be inserted inappropriately with liability of posterior knee structures injury. |
| anterior opening osteotomy       | Directed proximal to the PCL insertion.     | To facilitate the proximal fragment manipulation, avoid any change in the PCL tension, and to obtain a stable hinge. |
|                                  | Under image control                         |                                                                          |
| Making the anterior open wedge   | Do not violate the posterior cortex and     | If not done under image control, posterior knee structures can be damaged. |
| osteotomy                        | leave a posterior hinge for opening the     | Cutting the posterior cortex may damage the posterior knee structures and will result in an unstable proximal fragment with inability to open the osteotomy appropriately. |
|                                  | osteotomy.                                  | A blunt saw blade increases the operative time and increases the incidence of bone necrosis and infection. |
|                                  | Use a sharp saw blade.                      | No irrigation will increase the incidence of thermal bone necrosis and infection. |
|                                  | Continually irrigate with saline while      | Presence of the K-wires in the proximal fragment prevents intraarticular propagation while opening the osteotomy. |
|                                  | cutting with the saw.                       |                                                                          |
|                                  | Put the saw blade in contact and parallel to|                                                                          |
|                                  | the K-wires inferiorly.                     |                                                                          |
|                                  | Make the cut inferior to the K-wires leaving|                                                                          |
|                                  | the K-wires in the proximal fragment.       |                                                                          |
| Anterior opening of the osteotomy| Under image control to precisely control the| Without using these tools (image and ruler), the degree of correction will be inappropriate. |
|                                  | amount of anterior opening and the degree of | Rapid opening may break the posterior cortex, resulting in an unstable situation. |
|                                  | tibial slope correction.                    |                                                                          |
|                                  | Use a surgical ruler to measure the amount  |                                                                          |
|                                  | of anterior opening according to the        |                                                                          |
|                                  | preoperative measurements.                  |                                                                          |
|                                  | Open the osteotomy gradually with the use   |                                                                          |
|                                  | of a lamina spreader or the insertion of    |                                                                          |
|                                  | multiple osteotomes.                        |                                                                          |
| Insertion of the iliac graft.    | Precisely size the graft according to the   | Wrongly sized graft wedges will result in an undesired change of the tibial slope. |
| Repositioning of the anterior     | desired amount of opening.                  |                                                                          |
| tibial fragment                  | Chamfer any bony prominences with a saw     | If not done, anatomic reduction will be hindered.                        |
|                                  | blade before reduction.                     | If not reduced anatomically, the patellar height may be affected.        |
| Fixation of the anterior fragment| Use proximal and distal screws in a lag     | Avoid overpenetration of the posterior cortex with the drill bit or long screws to avoid any injuries of the posterior structures. |
|                                  | manner.                                     |                                                                          |

PCL, posterior cruciate ligament.
surgical soft-tissue tensioning, muscular strengthening, bracing, and gait pattern correction. Osteotomy in soft-tissue GR pattern is mostly a varus correcting osteotomy and is directed at protecting the reconstructed ligaments rather than correcting the recurvatum deformity. Mixed-type GR can be managed by osteotomy alone or in combination with soft tissue tensioning procedures.6

In this article, we describe a technique to correct a unilateral GR deformity with inverted tibial slope,

Table 2. Advantages and Disadvantages of the Technique

| Advantages                                                                 | Disadvantages                  |
|----------------------------------------------------------------------------|--------------------------------|
| Bone of the anterior part of the proximal tibia is used as a biological plate. Decreasing the amount of hardware has the advantage of lowering the cost, decreasing the incidence of infection, and reducing the need for future hardware removal. Using autogenous iliac bone graft has the advantage of decreasing disease transmission associated with allograft. It also is cost-effective compared with artificial bone substitutes. | Increased operative time. Increased patient morbidity. Surgically demanding. |

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Fig 1. Preoperative planning. Lateral plain radiograph of the left knee. The yellow line is tangent with the tibial plateau. The red line is perpendicular to the yellow line. The blue line is tangent with the posterior tibial cortex and intersects with the yellow line making the tibial slope angle, which in this case was $79^\circ$, denoting a reversed tibial slope, Osgood-Schlatter disease of the tibial apophysis (yellow arrow).

Fig 2. Patient position and surgical landmarks. Front image of the left knee while the patient supine and the knee are extended, showing the landmarks for performing knee arthroscopy and open correction of the recurvatum deformity. (HALP, high anterolateral portal; PT, patellar tendon and the patella; TT, tibial tuberosity.)
mostly due to Osgood-Schlatter disease. Correction is
done by performing an anterior open-wedge osteotomy
of the proximal tibia and impaction of 2 wedges of
autogenous iliac bone grafts within the osteotomy. The
proximal portion of the tibia is cut in the coronal plan
and is used as a biologic plate for fixation with no need
for additional hardware (e.g., plate or staples) for fixa-
tion of the osteotomy.

Surgical Technique (With Video Illustration)
This article describes step-by-step correction of a GR
and a reversed tibial slope by anterior open-wedge high
tibial osteotomy and autogenous iliac bone grafting.
The upper tibial bone is used as a biological bone plate
(Video 1). Advantages and limitations are summarized
in Table 1, and pearls and pitfalls are summarized in
Table 2.

Preoperative Planning
The tibial slope is measured on a lateral view plain
radiograph of the knee. A line is drawn tangent with
the tibial plateau. Another line is drawn along the
posterior tibial cortex and intersects with the plateau
line to form the tibial slope angle, which in this case was
79°, denoting a reversed tibial slope. A third is drawn
perpendicular to the tibial plateau tangent line to show
the needed degrees of correction (Fig 1).

Patient Position and Surgical Landmarks
After induction of anesthesia, the patient is placed in
the supine position. Landmarks for arthroscopic and
surgical work are drawn (Fig 2). The patient is exam-
ined under anesthesia. A high thigh nonsterile padded
tourniquet is then applied. The patient is then prepared
and draped in the usual manner. A tricortical autoge-
nous iliac graft is taken and prepared.

Knee Arthroscopy
Routine knee arthroscopy is performed (Hopkins II;
Karl-Storz, Tuttingen, Germany). Any chondral or
meniscal pathology is managed.

Surgical Technique
A 10- to 15-cm surgical incision is made on the
anterior aspect of the tibia just lateral to the tibial shin
and starting just proximal to the tibial tuberosity (Fig
3A). Muscles on the anterolateral aspect of the
Fig 4. Steps of creating the biological bone plate (10-15 cm long) by performing an osteotomy of the proximal tibia of the left knee in the coronal plan. (A-B) Front image of the left knee while the patient is supine and the knee extended. While Hohmann retractors are placed subperiosteally, the bone of the proximal tibia is cut horizontally with a saw blade. (C) The bone cut is completed with an osteotome to create a bone segment of about 15 cm long (biological bone plate). (D) The bone segment is reflected proximally and wrapped with a wet towel.

Fig 5. Insertion of K-wires at the site of osteotomy. (A) Front image of the left knee while the patient is supine. Two parallel K-wires are inserted in the proximal tibia from anterior to posterior at the desired osteotomy site and directed to a point just proximal to the posterior cruciate ligament insertion. (B) Fluoroscopic lateral view of the left knee taken intra-operatively as Image control is mandatory to precisely locate the k-wires.
Fig 6. Performing the anterior open-wedge correcting osteotomy. (A) Front image of the left knee while the patient is supine showing a saw blade used to perform the bone cut from anterior to posterior, guided by the previously inserted K-wires. (B) Fluoroscopic lateral view of the left knee taken intraoperatively as image control is mandatory to control the bone cut that is made by a saw blade from anterior to posterior, parallel and inferior to the inserted K-wires to avoid intra-articular propagation while opening the osteotomy. Care is taken not to cut the posterior tibial cortex and leave about 5 mm of bone from the posterior cortex as a hinge for the osteotomy.

Fig 7. Opening the correction osteotomy. (A) Front image of the left knee while the patient supine and the knee flexed showing anterior opening of the osteotomy by the sequential insertion of multiple osteotomes. (B) Fluoroscopic lateral view of the left knee taken intraoperatively as to control the amount of osteotomy opening and avoiding posterior cortex violation. (C) Front image of the left knee while the patient supine and the knee flexed, the amount of anterior wedge opening is measured according to the preoperative plan.
proximal tibia are lifted subperiosteally to expose the proximal tibia (Fig 3B). The site of osteotomy is marked with an electrocautery (Fig 3C). While Hohmann retractors are placed subperiosteally, the bone of the proximal tibia is cut horizontally with a saw blade. The bone cut is completed with an osteotome to create a bone segment of about 15 cm long (biological bone plate). The bone segment is reflected proximally and wrapped with a wet towel (Fig 4 A-D).

Under image control, 2 parallel K-wires are inserted in the proximal tibia from anterior to posterior at the desired osteotomy site and directed to a point just proximal to the posterior cruciate ligament insertion (Fig 5A and B).

Under image control, the bone is cut with a saw blade from anterior to posterior, parallel, and inferior to the inserted K-wires to avoid intra-articular propagation while opening the osteotomy. Care is taken not to cut the posterior tibial cortex and leave about 5 mm of bone from the posterior cortex as a hinge for the osteotomy (Fig 6A and B).

Under image control, the osteotomy site is opened by the sequential insertion of multiple osteotomes (Fig 7A and B). The amount of anterior wedge opening is measured according to the preoperative plan (Fig 7C).

Two wedges of autogenous iliac bone graft are shaped according to the desired correction size and are inserted to fill the osteotomy gap (Fig 8A-D). Any bone prominence is chamfered with the saw, then the bone plate is reduced and fixed with small fragment lag screws proximal and distal to the osteotomy (Fig 9A-E). Stability is checked, the wound is closed, and the knee is put in a brace.

**Discussion**

Coronal plane deformities in the proximal tibia are the most commonly treated deformities and varus- or valgus-producing high tibial osteotomies have been

![Fig 8. Impaction of the autogenous iliac graft into the osteotomy site. (A) A saw blade is used to cut the autogenous iliac bone graft into two wedges of bone. (B) Two wedges of autogenous iliac bone graft are shaped according to the desired correction size. (C) Front image of the left knee while the patient supine and the knee flexed showing the impaction of the 2 bone wedges into the osteotomy gap. (D) Fluoroscopic lateral view image of the left knee taken intraoperatively showing the corrected tibial slope after the impaction of the bone wedges.](image)
well described in the literature. Sagittal plane deformities, however, have not gained as much attention due to their relatively uncommon presentation and necessity for surgical management.10

The most common presentations of patients with GR are anterior knee pain, knee instability, patellofemoral instability, and difficult walking on an uneven ground.6,11

The exact cause of anterior knee pain is not well known; however, this may be related to chronic inflammation and impingement of the hypertrophied fat pad behind the patella when the knee is extended.11

A recurvatum knee is inherently very unstable. Knee instability usually results from the dysfunction of the locking mechanism, quadriceps wasting, and abolition of the patellofemoral lever arm. Pseudo-patella alta in a recurvatum knee is the likely cause of patellofemoral instability.6

It may be difficult to decide whether or not to operate on a recurvatum knee. Knee hyperextension is not itself abnormal. Constitutional hyperextension of the knee of up to 15° has been found to be physiological in 40% of the population of normal control and is commonly bilateral, symmetrical, and asymptomatic. No intervention is needed for constitutional hyperextension of the knee.6,10,12

Surgery is generally indicated in the symptomatic (pain, instability), pathologic GR with an associated causative correctible deformity (bony, soft tissue, or a combination of both).10 More specifically, osteotomy is indicated when there is a pure bony cause for the GR (i.e., reverse of the tibial slope). The tibial slope can be

Fig 9. Reduction and fixation of the biological bone plate. (A) Front image of the left knee while the patient is supine and the knee flexed. Any bony prominence is chamfered with the saw. (B) Reduction of the bone plate. (C) Fixation of the bone plate with small fragment lag screws proximal and distal to the osteotomy. (D) Intraoperative lateral image of the left knee showing correction of the deformity and final fixation. (E) Intraoperative anteroposterior image of the left knee showing correction of the deformity and final fixation.
reversed due to damage of the TT physis for any reason, e.g., trauma, fracture, osteomyelitis, patellar tendon graft harvesting before skeletal maturity, Osgood-Schlatter disease, prolonged immobilization, or radiotherapy. Another rare bony factor is hypoplasia of the lateral femoral condyle resulting in hyperextension of the tibia together with excessive external rotation and subluxation of the tibia on the femur.6,10

Osteotomy is indicated also in the mixed-type GR (bony and soft tissue) as in poliomyelitis. The problem starts with bony changes as the patient has a weak quadriceps and subsequently hyperextends his or her knee to lock it while walking. Knee hyperextension results in reversing the tibial slope followed by gradual stretching of the posterior soft tissues and unstable knee. However, in these patients, the recurvatum should not be overcorrected to preserve the passive lock-home stabilizing mechanism.6,10,13

Pure soft-tissue GR may be traumatic in origin (e.g., following posterior knee dislocation) or nontraumatic (gradual stretching of the posterior structures). Osteotomy alone has a much lesser role in the pure soft-tissue pattern and is mainly a varus correcting osteotomy done to protect the reconstructed ligaments.6

Many types of osteotomy techniques have been described in the literature to correct bony recurvatum. Irwin described a posterior- closing wedge osteotomy below the level of the TT with fibular osteotomy.14 Bowen et al.15 described a posterior closing-wedge osteotomy above the level of the TT.

Anterior opening-wedge osteotomy may be done proximal to the TT, as described by Lexer,16 Bohn,17 and Brett,18 at the level of the TT with tibial tubercle osteotomy as described by Lecuire et al.,12 or distal to the TT as described by Campbell.19

Generally speaking, osteotomies below the TT are associated with low healing potential, with the osteotomy level being far from the site of bony deformity, necessitating a greater angular correction and adding a fibular osteotomy.6 Osteotomies above the TT are close to the site of deformity; however, the epiphyseal fragment is small, prone to necrosis, and with a less-stable posterior hinge. This type of osteotomy affects the patellofemoral functions.5

Our technique is performed by making an anterior opening-wedge osteotomy at the level of the TT with a posterior hinge situated just proximal to the posterior cruciate ligament insertion. This site of osteotomy in the metaphyseal bone has a high healing potential, close to the site of deformity, and does not affect the patellofemoral functions. A long segment of the proximal tibia is cut in the coronal plane and is used as a biological plate for osteotomy fixation.

Many implants have been used for fixation of the osteotomy as staples or plates.10,20 In our technique, we used a long segment of the proximal tibia as a biological plate for osteotomy fixation.

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