Planning of the Multiplanar Osteotomies for Correction of Complex Tibial Deformities

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Abstract — Despite improvements in imaging techniques and methods of internal and external fixation, the study of the geometry of deformities remained greatly unexplored until the past 10 years. The level of the apex of deformity was always considered intuitively, and the level of osteotomy relative to the apex depended on the location of the physis and the space needed for the hardware. Paley et al. described the concept of the center of rotation of angulation (CORA). They developed a simple method to identify rapidly and accurately the level of the CORA. Because the concepts of the CORA and the axis of correction are basic principles of deformity correction, they are independent of the method of fixation used. One-step surgical management of the complex tibial deformities is an original technique that results in a decrease in both hospital stay and the number of operations. For these reasons, it could be classified as a minimal invasive procedure. This, however, does not eliminate the need for regular follow-up; this type of treatment requires full patient and family collaboration.

Keywords: multiplanar osteotomies, CORA, tibial deformities.

1. INTRODUCTION

Limb deformities can be classified according to cause (congenital, developmental, posttraumatic), location (bone or joint contracture, extra- or intraarticular), geometry (angulation, translation, rotation, length discrepancy), severity (magnitude), and progression (static or progressive). Orthopedic surgical correction must consider all of these factors [1]. Limb deformities may lead to dysfunction, pain, and joint degeneration. To patients, appearance may be of primary concern. For bone deformities, the mainstay of treatment has been osteotomy, whereas for joint-contracture deformities, extra- and intraarticular soft-tissue releases have been the standard of treatment [1]. Many innovative osteotomies have been developed to treat limb deformities. The results are frequently subjectively acceptable but objectively inaccurate. Secondary deformities often result from primary correction. The significance of this has only recently been recognized [2, 3]. Inaccuracy of correction in children has often been excused by the time-honored pediatric orthopedic motto, "It will remodel with time." In some cases, this has been true. In many cases, however, residual and secondary translation and angulation deformities have gone untreated into adult life. Although most of these residual and secondary deformities are asymptomatic in children, many lead to degenerative changes and disability in adults. During the 20th century, high postoperative complication rates were often reported: neurovascular complications owing to acute correction with stretch injury and compartment syndromes [4] and bone complications owing to extensive exposure and methods of fixation. During the last 10 years of the 20th century, a revolution occurred in the management of children's deformities because of improved biologic and mechanical techniques. Gradual correction reduces the operative exposure needed to cut the bone [5]. Acute surgical morbidity is greatly reduced by these percutaneous techniques. Furthermore, progressive correction avoids stretch damage to the neurovascular structures that are at risk. The magnitude of correction, which was previously the limiting factor in how much deformity correction could be achieved, is no longer an obstacle with gradual correction of bone or joint deformities. The accuracy of correction, which was usually only +/-5°, improved greatly [6] with gradual correction because of postoperative adjustability of external fixation.

With the advent of radiographs just over 100 years ago, our understanding of the geometry of deformities increased greatly. A wide variety of configurations of osteotomy were developed to correct these deformities. The most commonly used have been the opening and closing wedge osteotomies and the dome osteotomy [1]. Despite improvements in imaging techniques and methods of internal and external fixation, the study of the geometry of deformities remained greatly unexplored until the past 10 years. The level of the apex of deformity was always considered intuitively, and the level of osteotomy relative to the apex depended on the location of the physis and the space needed for the hardware. This approach more often than not created secondary translation deformities. Paley et al. [2, 3] described the concept of the center of rotation of angulation (CORA). They demonstrated that when the axis of correction and the osteotomy are at a level different from that of the CORA, secondary translation deformities occur. They developed a simple method to identify rapidly and accurately the level of the CORA. Because the concepts of the CORA and the axis of correction are basic principles of deformity correction, they are independent
of the method of fixation used. Although in the past, the
tendency has been to make the osteotomy accommodate
the fixation, the current concept is to consider the
principles of deformity correction as preeminent and to
make the fixation and osteotomy adhere to the principles.
In other words, instead of osteotomy being slave to
fixation, fixation becomes slave to osteotomy. With this
approach, we can eliminate secondary deformities after
osteotomy [1].
A more recent development has been to harness the
capriciousness of the physe by temporary
hemiepiphyseal stapling [7]. Epiphyseal stapling was a
popular method for treating angular deformities in
adolescence during the 1960s and 1970s. It became less
popular as osteotomy techniques improved during the
1980s and 1990s. Stevens et al. [8] recently showed that
it is a safe technique to use in young children, with little
risk of growth plate closure.

2. MATERIAL AND METHOD

Five limbs in four patients presenting with tibia vara were
operated on between 2004 and 2005. There were three
girls and one boy. Average age at surgery was 8 years 6
months. The diagnosis at initial presentation was: vitamin
D-resistant hypophosphataemic rickets (VDRR) in two
cases, Blount’s disease in one case and genu varum post
septic osteoarthritis of the knee in one case. Two patients
had previously undergone two valgus osteotomies each.
Patients were analyzed clinically and radiologically
according to leg axis and length, knee mobility and
stability and pain.

2.1. Preoperative Planning

Angular deformity of the tibia involves angulation not
only of the bone but also of its axes.
We calculated the amount of deformation using the Paley
et al. method. The point at which the proximal and distal
axis lines intersect is called the center of rotation of
angulation (CORA). The axis line of the proximal bone
segment is called the proximal mechanical axis (PMA) or
proximal anatomic axis (PAA) and the axis line of the
distal bone segment is called the distal mechanical axis
(DMA) or distal anatomic axis (DAA) [9].
We drawn the PMA or PAA and the DMA or DAA lines
and identified the CORA at their points of intersection.
We measured the magnitude of angulation in the frontal
plane.
When rotation and angulation deformities are both
present, the axis of rotation and the axis of angulation can
be defined as two separate axes or can be resolved into
one axis that defines both deformities. The axis of
angulation is in the transverse plane. The axis of rotation
is the longitudinal axis that is perpendicular to the
transverse plane. That axis that defines both angulation
and rotation is inclined between the longitudinal and the
transverse axes of rotation and angulation, respectively
[9].
We calculated the orientation of this longitudinally
inclined axis using a modification of the graphic method.

2.2. Operative Technique

The first step is a 2-cm segmentary resection of the
fibular diaphysis at the junction between the middle and
lower third.
We then expose the anteromedial aspect of the tibial
metaphysis or diaphysis at level of the determined
CORA.
Combined torsional and angular deformities of the tibia
are corrected creating a single osteotomy which is
oriented so that rotating the two fragments on the created
osteotomy plane allows correcting all deformities in one
step (Figure 1).

Figure 1. The orientation of the osteotomy plane

3. RESULTS

3.1. Case Presentations

Patient 1

A 14 years old girl presented with vitamin D-resistant
hypophosphataemic rickets (VDRR), for which she
underwent two valgisation/derotation osteotomies on the
left side. On the left side she had 16° varus deformity and
32° procurvatum of the tibia.

Figure 2. Patient 1: 32° procurvatum deformity in the
sagital plane, 16° varus deformity in the frontal plane and
no deformity in the 30° oblique plane
She had no limb length discrepancy. Radiographs showed 16° varus deformity in the frontal plane and 32° procurvatum deformity in the sagittal plane. 30° oblique radiograph showed no deformity of the tibia (Figure 2). We performed the correction osteotomy in the transverse plane, inclined 30° from the sagittal plane. The stabilization of the osteotomy was obtained by an external fixator. The fixator was removed 3 months postoperatively. No pin-site infection was observed. At 1 year follow-up, the patient had normal leg alignment, no limb length discrepancy and no pain (Figure 3).

Figure 3. Patient 1: postoperative appearance

Patient 2
A 3 years old girl presented with left Blount’s disease (Figure 4). She had 35° internal rotation and varus deformities on the left side. Radiographs showed 30° metaphysodiaphyseal angle (MDA) on the left side. We performed a single-cut osteotomy on the left side, followed by percutaneous K-wires fixation and long leg plaster cast immobilization for 6 weeks. At plaster cast removal we removed the K-wires also. At follow-up the girl had normal leg alignment (Figure 5).

Average follow-up was 8 months. Average preoperative varus deformity was 23.2° versus 3.5° after correction. Average preoperative internal rotation was 29.6° compared to 1.8° postoperatively. The fixation hardware was left in place for an average of 6 weeks, allowing a longer period (8 months) for the patient who required limb lengthening. The patients were satisfied and had no residual deformities. Radiographically, all patients had correct alignment and articular congruency. We had only one complication: pin-site infection requiring oral antibiotics.

Figure 4. Patient 2: Left Blount’s disease, before operation

Figure 5. Patient 2: Left Blount’s disease, after operation

4. DISCUSSIONS

The prerequisite for treatment is evaluating the magnitude of all tibial deformities. Using the Paley’s method of preoperative planning, we are able to evaluate and correct all deformities in one step avoiding secondary deformations due to osteotomy.
When rotation and angulation deformities are both present, the axis of rotation and the axis of angulation can be defined as two separate axes or can be resolved into one axis that defines both deformities (Figure 6) [9].

![Figure 6. The axis of deformation for angulation is in the transverse plane. The axis of deformation for rotation is longitudinal. The axes of angulation and rotation can be resolved into a single axis in a longitudinally inclined orientation (After Paley et al. [9])](image1)

The axis of angulation is in the transverse plane. The axis of rotation is the longitudinal axis that is perpendicular to the transverse plane. The axis that defines both angulation and rotation is inclined between the longitudinal and the transverse axes of rotation and angulation. The orientation of this longitudinally inclined axis can be calculated using trigonometric formulae or can be approximated using a modification of the graphic method [9].

The angulation-rotation deformities have been resolved to a single axis of rotation. An osteotomy can be made perpendicular to that axis. Rotation of the osteotomy about that axis will simultaneously correct angulation and rotation, while maintaining contact between the inclined osteotomy surfaces [9].

![Figure 6. The plane of osteotomy is perpendicular to the angulation-rotation axis, resulting in one-step correction of both angulation and rotation (After Paley et al. [9])](image2)

Lower limb frontal and sagittal plane alignment and joint orientation have significant consequences for function and wear on the hip, knee and ankle. There is a normal range for the orientation of these joints relative to the mechanical and anatomic axis of the femur and/or tibia. We can use the normal joint orientation to accurately plan realignment of a deformed femur or tibia. In the frontal plane we use both anatomic and mechanical axis lines for planning. In the sagittal plane, the mechanical axis has less relevance and, therefore, only the anatomic axis is used for planning [9].

5. CONCLUSIONS

One-step surgical management of the complex tibial deformities is an original technique that results in a decrease in both hospital stay and the number of operations. This, however, does not eliminate the need for regular follow-up; this type of treatment requires full patient and family collaboration.

This comprehensive approach allow restoration of the mechanical and anatomic axes of the lower limb in patients with tibia vara, resulting in a resolution of symptoms as a result of normalization of the weight-bearing forces across the knee and ankle. We believe that this approach will decrease the risk of early degenerative arthritis of the knee.

6. REFERENCES