



Evaluation of Safety and Efficacy of Distal Nail Implant for Correction of Coronal Plane Deformity: A Prospective Observational Study

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Abstract

Introduction: Coronal plane deformities of the distal femur can significantly impact knee biomechanics and patient quality of life. While various surgical techniques exist for correction, the use of distal femoral nails presents a potentially advantageous approach. This study aims to evaluate the efficacy and safety of distal femoral nails in correcting coronal plane deformities of the distal femur.

Methods: A prospective study was conducted on 30 patients with distal femoral coronal plane deformities. Patients underwent correction using distal femoral nails. Pre- and post-operative assessments included radiographic measurements, functional scores (Lysholm), and complication rates.

Results: The majority of patients (63.3%) were aged 20-40 years. Significant improvements were observed in radiographic parameters, with medial joint space width increasing from 2.9 ± 1.5 mm to 27.1 ± 6.7 mm post-operatively. The mean time for union was 11.4 ± 3.4 weeks. Lysholm scores improved substantially, with 86.7% of patients achieving fair to excellent scores post-operatively compared to 100% poor scores pre-operatively. Complication rates were low, with no cases of non-union reported.

Conclusion: The use of distal femoral nails for correcting coronal plane deformities of the distal femur demonstrates promising results, with significant improvements in both radiographic and functional outcomes. The technique appears to be safe and effective, offering good stability and allowing for early rehabilitation.

Keywords: Distal femur, Coronal plane deformity, Distal femoral nail, Osteotomy, Knee alignment, Functional outcome, Lysholmscore

Introduction

Coronal plane deformities of the distal femur, including valgus and varus malalignments, can lead to abnormal loading of the knee joint. This is associated with accelerated cartilage wear, early osteoarthritis, and knee pain [1].

The coronal plane deformities affecting the long bones of the lower extremities of the distal femur may emerge verities of reasons including trauma sequel, metabolic disorders, skeletal dysplasia, infection and congenital limb deficiencies. The coronal deformities may predispose to pain and instability, ligament injury and cartilage degeneration. In addition, those deformities around the knee may deteriorate ambulatory

capacity of individual patient [2-4].

Genu Valgum deformity of distal femur may cause knock knees and deteriorate feet position during the stance phase. The patellofemoral joint subluxates laterally as the q angle increases which inturn may cause patellofemoral joint instability. In long term mechanical loading on the lateral compartment of the knee potentially may cause chondral degeneration eventually leading to osteoarthritis. Correction of Genu Valgum deformity can balance the load distribution in the knee and prevent long term effect of malalignment.

For severe deformities, realignment osteotomies are often required to unload the affected compartment and correct



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DOI: <https://doi.org/10.13107/jmt.2024.v10.i01.218>

malalignment [5]. Traditionally, these osteotomies have been done open with plate fixation [6]. However, they carry substantial risks such as infection, stiffness, and wound complications [7]. Several treatment options for coronal plane deformity of distal femur including growth guided surgery, osteotomy and distal femoral nailing is the treatment of choice in patient who has multiplanar deformities along with limb, length inequality [8].

More recently, there has been interest in using intramedullary implants to achieve distal femoral osteotomy fixation while minimizing surgical dissection [9]. Specifically, distal femoral nail implants have been developed for this application. They can be inserted through a small incision and provide stable internal fixation, potentially enabling early mobilization and accelerated recovery [10].

This prospective study was conducted to analyse management of coronal plane deformity of distal femur using distal femoral nail.

Aim & Objectives

AIM: To analyse the correction of coronal plane deformity of distal femur using distal femoral nail

Objectives: To compare the functional outcome among coronal plane deformity of distal femur treated with distal femoral nail in terms of the following

- Intra operative time
- Blood loss
- Time for union
- Knee range of movements
- Deformity correction
- Knee society score

Review of literature

Anatomy of femur

Introduction

The femur is the longest, heaviest, and strongest human bone. At the proximal end, the pyramid-shaped neck attaches the spherical head at the apex and the cylindrical shaft at the base. There are also two prominent bony protrusions, the greater and lesser trochanter, that attach to muscles that move the hip and knee. The angle between the neck and shaft, also known as the inclination angle, is about 128 degrees in the average adult. However, the inclination angle decreases with age [11, 12]. The adductor tubercle for the attachment of the posterior half of the adductor magnus and the linea aspera are other important features.

The hip is a ball-in-socket joint composed of the acetabulum of the pelvis encompassing the femoral head. The head is pointed in a medial, superior, and slightly anterior direction. The ligamentum teres femoris connects the acetabulum to the fovea capitis femoris, which is a pit on the head.

The shaft has a mild anterior arch. At the distal femur, the shaft

flares out in a cone shape onto a cuboidal base of the medial and lateral condyle. The medial and lateral condyles join the femur to the tibia, forming the knee joint.

Both the hip and the knee joints are synovial joints covered by cartilage to reduce friction and optimize the range of motion. The bony features serve as landmarks for measuring the axis along the femur [13, 14].

Distal femur

The distal femur forms the upper part of the knee joint and plays a crucial role in lower limb biomechanics. Its complex anatomy can be divided into several key structures:

Condyles: The distal femur features two large, rounded prominences called condyles. The medial condyle is slightly larger and more prominent than the lateral condyle. These condyles articulate with the tibial plateau to form the tibiofemoral joint, the primary weight-bearing component of the knee.

Intercondylar notch: Between the condyles lies the intercondylar notch, a deep groove that houses the anterior and posterior cruciate ligaments. These ligaments are vital for knee stability and proper joint function.

Articular surfaces: The condyles are covered with smooth hyaline cartilage, allowing for low-friction movement within the joint. The patellar surface, located anteriorly between the condyles, articulates with the patella to form the patellofemoral joint.

Epicondyles: Located on the non-articular sides of the condyles, the epicondyles serve as attachment points for various ligaments and tendons. The medial epicondyle provides attachment for the medial collateral ligament, while the lateral epicondyle anchors the lateral collateral ligament.

Adductor tubercle: This small bony prominence on the superior aspect of the medial epicondyle serves as the attachment site for the adductor magnus tendon.

Supracondylar lines: These ridges extend proximally from the condyles, with the medial supracondylar line being more prominent. They provide attachment points for the intermuscular septa and various muscles.

Popliteal surface: Located posteriorly between the condyles, this area forms part of the floor of the popliteal fossa, a diamond-shaped space behind the knee.

Metaphysis: The region just above the condyles, characterized by its wider cross-section and trabecular bone structure, plays a crucial role in load distribution and is a common site for fractures in older adults.

Blood supply: The distal femur receives its blood supply primarily from the superior and inferior genicular arteries, branches of the popliteal artery. This rich vascular network is essential for bone health and healing.

Structure and function

The main functions of the femur are weight bearing and gait

stability. The weight of the upper body rests on the two femoral heads. The capsular ligament is a strong thick sheath that wraps around the acetabulum periosteum and proximal femur [15]. This ligament holds the femoral head within the acetabulum of the pelvis. The capsular ligament limits internal rotation but allows for external rotation [16, 17].

The knee is a hinge joint between the distal femur and proximal tibia. The medial and lateral meniscus stabilize and cushion the tibiofemoral articulation. The medial and lateral ligaments prevent valgus or varus deformity. Within the knee joint, the anterior and posterior cruciate ligaments allow for some rotational movement of the knee while preventing anterior or posterior displacement of the tibia. The patellofemoral joint is used in knee extension [18, 15].

Embryology

The limb bud development of the femur and lower limb begins with the cells of the lateral plate mesoderm. These cells become activated in week four and form the limb bud. The lower limb forms soon after the upper limb bud [19].

The apical ectodermal ridge of the limb bud induces limb growth and development. The lateral plate somatic mesoderm of the lower limb bud gives rise to the femur, which develops from endochondral ossification, in which bone replaces hyaline cartilage models. Articular cartilages and epiphyseal plates develop by intramembranous ossification, a process in which there is no cartilage model.

The lateral plate somatic mesoderm also gives rise to tendons, the perimysium, and the epimysium. The myotomic component of the somites generates the muscles of the femur. The periosteum surrounds the femur and serves a nutrient function through the adjacent blood supply. The compact bone of the femur provides strength; it is greatest in the middle third of the femur, where the stresses are highest.

Blood Supply and Lymphatics

The femoral artery is the main blood supply to the lower extremity. This artery is the major branch of the external iliac artery after crossing the ilioinguinal ligament. The medial and lateral circumflex arteries are branches of the femoral artery. Along with the obturator artery, a branch of the internal iliac artery, these vessels supply the femoral head via significant anastomotic connections [20]. The foveal artery, a branch of the obturator artery that runs through the ligamentum teres femoris, acts as a supportive blood supply to the femoral head, albeit not the primary source.

At the level of the lesser trochanter, the femoral artery bifurcates into the deep and superficial femoral artery. The perforating branches of the deep femoral artery supply the shaft and the distal portion of the femur [21, 22].

Muscles

The thigh muscles are divided into the anterior, medial,

posterior, and gluteal compartments. The femur is located within the anterior compartment.

Anterior Compartment Muscles

The anterior compartment is composed of muscles that are mainly used for hip flexion and knee extension. The hip flexors include the pectineus, iliopsoas, and the sartorius muscle. The femoral nerve innervates all the hip flexors other than the iliopsoas. The iliopsoas muscle is the most powerful hip flexor, and it is composed of the psoas major and iliacus [23].

The iliacus arises from the iliac fossa, iliac crest, and ala of the sacrum and inserts on the lesser trochanter. The iliacus is innervated by the femoral nerve (L2-L3). The psoas muscle arises from the lateral aspect of the T12-L5 vertebrae and inserts with the iliacus on the lesser trochanter of the femur. The iliacus is innervated by the ventral rami of L1-L3. Taken together, the iliopsoas is the most powerful flexor of the thigh at the hip.

The pectineus arises from the superior pubic ramus and inserts on the pectineal line of the femur. The pectineus is innervated by the femoral nerve and serves as a flexor of the thigh at the hip, as well as assisting in the medial rotation of the thigh.

The sartorius arises from the anterior superior spine of the iliac bone and inserts on the medial surface of the tibia as part of the pes anserinus (goose's foot) tendon (composed of the tendons of the sartorius, gracilis, and semitendinosus). The sartorius is innervated by the femoral nerve (L2-L3) and flexes, abducts, and externally rotates the thigh and flexes the leg at the knee. The name sartor is Latin for tailor and is appropriate because tailors often sit on the floor cross-legged to hem a skirt or cuff a pair of pants.

A mnemonic for the sartorius is the FABER muscle. This stands for Flexion, Abduction, and External Rotation. Note that the sartorius is effective as a flexor of the thigh only when the leg is extended at the knee. If not, the muscle serves to flex the leg at the knee.

The quadriceps femoris muscle consists of the rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis. All four muscles insert onto the patella, which is then connected with the tibial tuberosity via the patellar tendon. All are innervated by the femoral nerve (L2, L3, L4). (Note that the more proximal muscles of this compartment are innervated by the femoral nerve (L2, L3), whereas the quadriceps femoris is innervated by the femoral nerve (L2, L3, L4). The rectus femoris arises from the anterior inferior iliac spine. The vastus medialis muscle arises from the medial lip of the linea aspera. The vastus lateralis arises from the greater trochanter and lateral lip of the linea aspera. The vastus intermedius arises from the anterolateral femur.

The further down the limb, the higher value of the ventral rami. This is termed the proximal-distal myotome principle.

Posterior Compartment Muscles

Posterior compartment muscles are mainly hip extensors and

knee flexors. They include the biceps femoris, semitendinosus, and semimembranosus muscles. The tibial division of the sciatic nerve (L5, S1, S2) innervates most of the posterior thigh muscles except for the biceps femoris. The biceps femoris has two heads, the long and short head. The long head is innervated by the tibial branch of the sciatic nerve (L5, S1, S2). The short head is innervated by the common peroneal (fibular) division of the sciatic nerve (L5, S1, S2) [23].

The superficial and deep layers of muscles organize the gluteal region. The superficial layer is composed of the gluteus maximus, medius, and minimus.

The gluteus maximus arises from the posterior aspect of the ilium, sacrum, coccyx, and sacrotuberous ligament and inserts on the gluteal tuberosity and iliotibial tract. The gluteus maximus is a powerful thigh extensor that is especially useful when arising from a chair or climbing a flight of stairs. The iliopsoas flexes the thigh at the hip to reach the next stair, but the gluteus maximus raises the body to the next level through its action in power extension.

The gluteus medius arises from the posterior aspect of the ilium between the anterior and posterior gluteal lines and inserts on the lateral aspect of the greater trochanter. The gluteus medius is innervated by the superior gluteal nerve (L5, S1). The gluteus minimus has a similar origin on the posterior aspect of the ilium. The muscle inserts on the lateral aspect of the femur and is innervated by the superior gluteal nerve (L5, S1).

Both muscles abduct and laterally rotate the thigh at the hip. They also prevent the pelvis from dropping when the contralateral leg is raised from the ground. These actions are also assisted by the tensor fasciae latae (TFL), which arises from the anterior superior iliac spine and inserts on the Gerdy tubercle on the tibia. The TFL is also innervated by the superior gluteal nerve (L5, S1).

The deep layer is composed of the piriformis, obturator internus, quadratus femoris and the superior and inferior gemellus muscles, and the obturator internus.

The piriformis muscle arises from the anterior sacrum and sacrotuberous ligament and inserts on the superior border of the greater trochanter of the femur. The piriformis is innervated by ventral rami of S1, S2.

The obturator internus arises from the bones surrounding the obturator foramen. The obturator internus is innervated by the nerve to the obturator internus (L5, S1). The obturator internus inserts on the medial surface of the greater trochanter. The deep muscles all laterally rotate the thigh when it is extended. They all abduct the flexed thigh at the hip and steady the head of the femur in the acetabulum. The superior gemellus is innervated by the nerve to the obturator internus (L5, S1). The inferior gemellus arises from the ischial tuberosity and inserts on the greater trochanter of the femur. The inferior gemellus is innervated by the nerve to the quadratus femoris (L5, S1). The quadratus femoris arises from the ischial tuberosity and inserts on the quadrate tubercle. The quadratus

femoris is innervated by the nerve to the quadratus femoris (L5, S1). Quadratus femoris laterally rotates the thigh at the hip and steadies the head of the femur in the acetabulum. These shorter and deeper gluteal muscles assist in the external rotation of the hip [23].

Medial Compartment Muscles

Adduction of the thigh at the hip is the primary function of the muscles of the medial compartment of the thigh. The muscles of this compartment include the adductor longus, adductor brevis, adductor magnus, gracilis, and obturator externus muscles. The obturator nerve is the principal nerve innervation of the medial compartment [24].

The adductor longus arises from the pubis and inserts on the middle third of the linea aspera. The adductor longus is innervated by the obturator nerve (L2, L3, L4) and serves to adduct the thigh.

The adductor brevis arises from the pubis and inserts on the pectineal line and linea aspera. The adductor brevis is innervated by the obturator nerve (L2, L3, L4) [24].

The adductor magnus is a complex muscle with a dual innervation. The anterior half arises from the ischiopubic ramus and inserts onto the linea aspera. This muscle is an adductor of the thigh at the hip, and it is innervated by the obturator nerve. The posterior part arises from the ischial tuberosity and inserts onto the adductor tubercle of the femur and receives innervation from the tibial aspect of the sciatic nerve (L4), and functions as a hamstring.

The gracilis arises from the body and inferior ramus of the pubis and inserts on the medial surface of the tibia as part of the pes anserinus (goose's foot) tendon. The gracilis is innervated by the obturator nerve (L2, L3); it laterally rotates the thigh and steadies the head of the femur in the acetabulum.

The obturator externus arises from the obturator foramen and inserts on the trochanteric fossa of the femur. The obturator externus is innervated by the obturator nerve (L3, L4) and laterally rotates the thigh and steadies the head of the femur in the acetabulum.

Alignment of lower limb

The alignment of the lower limb can be evaluated with standard radiographic techniques. However, the mechanical and anatomic axes of the lower limb are only precisely assessed if the ankle and hip positions are known. Standing views allow the assessment of the tibiofemoral knee compartments states, including the joint space. For evaluation of the patellofemoral joint, skyline or Merchant views are used. However, computerized tomography (CT) and magnetic resonance imaging (MRI) can give more subtle information. Definition of human normal limb alignment and malalignment are formulated from statistics. Thereby, the deformities of the lower limb are defined as a deviation of the physiological axes. Limb alignment deformities may have a congenital or

constitutional aetiology. During childhood they may be due to growth disorder with the premature closure of the epiphyseal plate. They are also associated with trauma, metabolic disorders such as rickets, or osteopathies such as renal osteopathy. Systemic myopathies or neurologic pathologies may also be related.

Posttraumatic deformities may occur after florid fracture healing. Other causes may be related to osteonecrosis of the knee, tumours, rheumatoid arthritis, and secondary to cartilage damage that follows major meniscal resections. The ultimate result is the secondary deviation of the mechanical axis of the lower limb [25].

Defining and measuring limb alignment

The anteroposterior (AP) projection full-length standing radiograph is the primary tool for evaluating the lower limb alignment. Lower limb alignment is best assessed by radiography in AP projection with a horizontally focused X-ray beam of the hip, knee, and ankle with the subject standing upright to support body weight. Patient positioning must be standardized to have reproducible results, especially leg rotation to get a flexion/extension plane aligned in the anterior-posterior direction.

The patella must be aligned in the anteroposterior projection with the centre of the femoral condyles. To achieve this position, 8–10° lateral rotation of the feet is classically needed. However, some situations, as seen in torsional deformities, cause medialization or lateralization of the patella. In these cases, the correct position is attained through the internal or external rotation of the lower leg until the patella is centred amongst the femoral condyles [26].

The weight-bearing X-ray of the entire lower limb is mandatory to evaluate the axis. The mechanical axis defined by the hip–knee–ankle line is measured on a full-length standing radiograph in the anteroposterior projection. It is considered a gold standard since it allows for consistent and precise measurement of mechanical tibiofemoral angle and assessment of limb deformities. However, in general practice, alignment is often inaccurately estimated using the anatomic tibiofemoral angle on standard anteroposterior weight-bearing X-rays, eventually causing imprecision in operative planning [26, 27].

When standard weight-bearing X-rays are used to calculate alignment, the estimated angle on the X-ray is called the anatomic tibiofemoral angle or femoral-shaft–tibial-shaft angle (FS–TS) (Fig. 3). This angle is defined by a line drawn from the centre of the proximal femoral shaft towards the knee and a line from the centre of the tibial shaft distal to the knee. To calculate the femoral and tibial shaft points, it usually is measured 10 cm from the knee joint to adjust the portion of the long-bone shafts commonly seen on a knee X-ray. In the tibia, both the anatomic and mechanical axes are similar.

It is possible that the anatomic tibiofemoral angle does not reproduce a correct estimation of the mechanical tibiofemoral angle. The anatomic tibiofemoral angle is valgus with an offset

of 4–6° for healthy individuals. In patients with knee osteoarthritis, the anatomic mechanical femoral angle ranges from 1.5° to 7°, with a low to a high correlation between the two measurements. Consequently, the variation of offset between the two angles is significantly greater in individuals with knee OA [26].

The femoral diaphysis silhouette affects the correlation between the mechanical and anatomic tibiofemoral angles. This correlation is affected by the lateral femoral bowing, the tibial bowing, and the proximal tibial angle by the rank of significance. The anatomic tibiofemoral angle estimation also shows more inaccuracy than the mechanical tibiofemoral angle determination. The inconsistency is amplified when the femur and the tibial anatomic axes are calculated using a smaller distance or lower length on their diaphysis. Consequently, it is highly recommended that the anatomic tibiofemoral angle should be obtained from a full-length weight-bearing radiograph to guarantee a correct determination of lower limb alignment [28]. This fact is even more critical for the preoperative planning of osteotomies around the knee and TKA.

Physiological axes and angles of the lower limb

The axes of the lower limb must be differentiated between anatomic and mechanical.

Anatomic axes of the femur and tibia

The anatomic axes of the femur and tibia are obtained from a line centred in the diaphysis of each bone. To determine the anatomic femoral axis, a line is drawn bisecting the femoral diaphysis into two parts. This line can be retrieved by joining two points in the middle of the medullar canal, one 10 cm above the knee joint and the other in the middle of the shaft, resulting in the distal anatomic femoral axis [29, 30]. The anatomic tibial axis bisects the tibial shaft, uniting two points, one proximally and other distally centred in the medullary canal. The anatomic femoral axis is not perpendicular to the axis of the tibia because of the deviation from the midline created by the femoral neck. Therefore, they form a physiological slight valgus angle.

Anatomic tibiofemoral angle

The anatomic tibiofemoral angle is measured between the anatomic axes of the femur and the tibia. This angle may be compared to the physiological value revealing the amount of deformity [31, 32]. The anatomical axes of the femoral and tibial diaphysis form a lateral angle of 173–175° (anatomic tibiofemoral angle/aTFA).

Mechanical axes of the femur and tibia

The femur and tibia mechanical axes are defined by the centre points of the hip, knee, and ankle joints. The femur mechanical axis is defined by a line from a point in the centre of the femoral head to a point in the centre of the knee. The femoral head

centre is easily found by drawing several bisecting lines corresponding to the head circumference diameter. To find the centre of the knee, several points may be used. A commonly used point is the centre of the tibial spines. Alternatively, Moreland et al [29] described a unique point on the knee that resulted from several measurements of different knee landmarks. Other authors define two different points for the centre of the knee. When drawing the mechanical axis of the femur, the distal point in the knee is marked in the centre of the femoral intercondylar notch. The centre of the tibial interspinous groove is then used as the starting point for the mechanical axis of the tibia. Using two different points at the knee brings some advantages: the identification of the tibial and femoral contributions to the deformity and the extent of the knee subluxation [26].

The mechanical axis of the femur forms a physiological angle of $6^\circ \pm 1^\circ$ with the anatomical femoral axis and is named the anatomical mechanical femoral angle (aMFA) [33]. The mechanical axis of the tibia is marked from the centre of the knee, previously assessed, and the centre of the talus or tibial plafond, defined using a ruler placed on the X-ray [26, 31, 32]. The tibial mechanical and the anatomic axes are almost indistinguishable. Consequently, it is assumed that both lines run physiologically parallel to each other.

Mechanical axis of the lower limb

The mechanical axis of the lower limb, also called the Mikulicz line, is drawn by connecting a point in the centre of the femoral head to a point in the centre of the ankle. This line's physiological position runs, on average, 4 ± 2 mm medial to the centre of the knee. Any deviation from this physiological range indicates either a valgus, if the line runs lateral, or a varus if it runs medially. The value of the deviation is measured in millimetres and is named mechanical axis deviation (MAD). The mechanical axis of the lower limb creates an approximate angle of 3° to the perpendicular axis of the body (Fig. 5) [34].

Deformities of lower limb

Deformities of the lower limb are defined as a deviation of the physiological axes in the frontal, sagittal or transverse planes and ultimately result in malalignment of the lower limb. Variations of the physiological longitudinal torque of the femoral and tibial diaphysis result in torsional deformities of the lower limb [25].

Frontal or coronal plane deformities

Most of the lower limb deformities occur in the frontal plane and are known as varus and valgus deviations. One frequent cause of secondary varus and valgus malalignment is the cartilaginous damage that results from a meniscectomy [38].

In the presence of a frontal plane deformity, a non-physiological load distribution occurs in the knee's medial or lateral

compartment. The resulting mechanical overload originates progressive cartilage wearing and progressive degenerative disease.

Genu valgum or Knockknees

Genu valgum or "knocked knees" are part of the coronal plane deformities of the lower extremity. The majority of patients are asymptomatic and have no functional limitations. This condition can be preceded by flat feet and occasional medial foot and knee pain. Children start developing physiologic genu valgum starting by age 2, and it becomes most prominent between ages 3 to 4. After that, it typically decreases to a stable, slightly valgus position by age 7 years. In the adolescent age group, minimal, if any, change in this alignment is expected. Intermalleolar distance has been used to assess the degree of genu valgum. It is the distance between the medial malleoli in a standing patient with touching medial femoral condyles. Intermalleolar distances greater than 8 cm is considered pathologic [35]. Rarely, in cases where valgus alignment continues to increase, it can be associated with an out-toed gait, lateral subluxation of the patella, and rubbing of the knees together as the child ambulates [36, 37].

Etiology [38]

Bilateral Genu Valgum

- Physiologic genu valgum
- Skeletal dysplasias
- Metabolic bone diseases
- Lysosomal storage diseases
- Overweight and obesity

Unilateral Genu Valgum

- Post-traumatic
- Tumors
- Infection

Epidemiology

Most patients present to the clinic between ages 3 to 5 years for the evaluation of genu valgum. The most common site of pathologic deformity is the distal femur, however, it can arise from the tibia as well [38].

History and physical examination

Most patients present to the clinic between ages 3 to 5 when parents generally become concerned about knocked kneed appearance. Bilateral genu valgum in this age group is typically physiologic but can also be secondary to skeletal dysplasia such as spondyloepiphyseal dysplasia and chondroectodermal dysplasia (Ellis van Creveld syndrome), metabolic bone diseases such as rickets (renal osteodystrophy and hypophosphatemic rickets), and lysosomal storage disease such as Morquio syndrome. Unilateral genu valgum is most often secondary to physeal or metaphyseal trauma. Radiographs

should be assessed for physeal narrowing, premature closing, and the presence of growth recovery lines (Park-Harris lines), giving attention to their morphology.

Cozen phenomenon is a post-traumatic valgus deformity seen after proximal tibial fractures [39]. Of note, this can be seen even in the presence of non-displaced fractures [40]. The most accepted theory of this phenomenon is the increased vascularity that occurs during fracture healing resulting in medial metaphyseal overgrowth. Other causes of genu valgum include radiation, infection, and tumors (osteochondromas, multiple hereditary exostoses, fibrous dysplasia).

Evaluation

Gait and rotational profile analysis are important aspects in the workup of angular deformities and help providers to identify the etiology of angular deformities, especially in the pediatric population. Primary or true valgus deviations about the knee can present as a stance-phase valgus thrust as seen in metabolic bone disease like renal osteodystrophy and longitudinal deficiency of the fibula that is associated with lateral femoral condyle hypoplasia. Secondary or apparent valgus gait deviations are associated with both axial and sagittal plane deviations. For example, increased femoral anteversion has an apparent valgus angulation attributed to internal rotation of the distal femur.

Radiographs are not indicated in children in the physiologic valgus phase. However, they are indicated in the setting of asymmetrical findings, excessive genu valgum clinically, age group beyond which is expected of physiologic changes, patients whose height falls below the tenth percentile for their age, and a history of trauma or infection. Radiographic assessment begins with obtaining weight-bearing long leg alignment images in which both patellae are facing forward. Coronal plane angulation of the lower extremities can be analyzed based on the deviation of the center of the knee from the mechanical axis and the tibiofemoral angle. The mechanical axis is a line connecting the center of the femoral head to the center of the ankle. In normal coronal alignment, the mechanical axis passes through the center of the knee. There is lateral and medial deviation of the center of the knee with respect to the mechanical axis of the lower extremity in genu varus (bowed legs) and genu valgum (knocked knee), respectively.

The tibiofemoral angle is the acute angle formed between the longitudinal axes of the tibial and femoral shafts. At birth, there is between 15 to 20 degrees of varus tibiofemoral angulation. As the child grows, this corrects to neutral by about age 2 and between 10 to 15 degrees of valgus tibiofemoral angulation between ages 3 and 4. At this point, the limb's valgus angulation then starts to gradually decrease to approximately 3-5 degrees of valgus by age 7. This is the residual normal coronal plane angulation of the lower extremity that will be carried to adulthood and should not increase [41].

It is important to determine whether the deformity is primarily originating from the femur or tibia. This is done by measuring the mechanical lateral distal femoral angle (angle between the femoral shaft and the mechanical axis of the femur) and medial proximal tibial angle (angle between the tibial plateau and mechanical axis of the tibia). The normal range of these angles is between 85 and 90 degrees [42].

Measurement of valgus deformity

To assess the degree of a deformity, the mechanical tibiofemoral angle should be measured. A straight line is drawn from the centre of the femoral head to the centre of the knee (mechanical axis of the femur) and projected downward beyond the knee. The mechanical tibial axis, running parallel to the shaft of the tibia, is also drawn. The angle formed by the portion of the line projected beyond the knee and the tibial shaft axis is then evaluated. A measurement of about 0°/180° implies an average axis of the limb. Otherwise, the resulting tibiofemoral angle corresponds to the degree of the deformity [31, 32].

To characterize the deformity (answering the 'how' question), either the position of the foot or the mechanical axis of the limb (Mikulicz line) may be used. According to the position of the foot, a valgus is determined if the foot is lateral to the femoral axis and a varus if the foot is medial. When assessing the mechanical axis of the limb, a deviation from this physiological range designates either a valgus, if the line runs lateral, or a varus if the line runs medial.

In certain situations, including height, obesity, and radiograph quality, the visibility of the femoral head may be impaired. In these cases, the tibiofemoral angle may be assessed by calculating the anatomic femoral axis and assuming the anatomical mechanical femoral angle as 6°, so the difference is taken as the amount of deformity. In this case, the anatomic tibiofemoral angle is used instead of the mechanical angle and compared with the assumed standard value of 6° of valgus [33]. In the case of an indistinct ankle joint, the tibial axis line should be drawn from the centre of the knee to a midpoint on the visible end of the tibia shaft.

Assessment of the deformity location

Due to the greater distance between the centre of the hip and knee joints than between the knee and ankle, the mechanical tibiofemoral axis runs slightly oblique, from cranio-lateral to medio-caudal, to the perpendicular axis of the body at an angle of approximately 3° [31, 32].

The tangent to the femoral condyles (knee baseline) and the tangent to the tibial plateaus, under physiological conditions, run almost parallel (joint line convergence angle = JLCA, 0-1 medial convergence).

The physiological femoral joint angle (FJA) is 2-3° valgus to the femoral mechanical axis and 8-9° valgus to the femoral shaft axis [31, 32].

The result of the parallelism between the mechanical and

anatomical axes of the tibia is that the anatomical and mechanical medial proximal tibial angle (aMPTA/mMPTA), between the tangent to the tibial plateau and the anatomical and mechanical axes, is 87 ± 3 in both cases. The anatomical and mechanical lateral distal tibial angle at the line of the ankle joint is 89 ± 3 [34,43].

Regarding the femur, the mechanical lateral distal femoral angle, calculated between the mechanical femoral axis and the baseline of the knee, is 87 ± 3 . The knee baseline forms an angle of 81 ± 2 with the anatomical axis of the femur [34,43].

Malalignment in the frontal plane is analysed using the 'malalignment test' (Fig. 6) and is the result of the deviation of the mechanical axis. A clinically significant deviation in the frontal plane is identified when the mechanical tibiofemoral axis runs more than 10 mm lateral to the centre of the knee joint (valgus deviation) or more than 15 mm medial (varus deviation). The origin of the deformity can be femoral, tibial, or both. Thereby, to evaluate the individual contribution, we must assess the mechanical lateral distal femoral angle (mLDFA, standard value 87 ± 3) and the mechanical medial proximal tibial angle (mMPTA, standard value 87 ± 3). If the mLDFA is lower than the standard value, a femoral valgus deformity is found [34,43].

Figure 8: Evaluation of the deformity using the malalignment test. (Notes. MAD, mechanical axis deviation; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle.)

In genu varum, the anatomic tibiofemoral angle (aTFA) is greater than $173-175^\circ$. The mechanical axis that runs from the centre of the femoral head to the centre of the ankle lays more than 4 ± 2 mm medial to the centre of the knee joint.

Figure 9: (A) Genu valgum: decreased anatomic tibiofemoral angle (aTFA $< 173-175^\circ$). The weight-bearing axis runs lateral to the 4 mm point and the distance between the medial malleoli (intermalleolar distance = IMD) is increased. The angle between the tibial plateau and the tangent to the femoral condyles (joint line convergence angle: JLCA) is opened medially. (B) Genu varum: increased anatomic tibiofemoral angle (aTFA $> 173-175^\circ$). The Mikulicz line runs medial to the 4 mm point (mechanical axis deviation: MAD > 15 mm medially) and the intercondylar distance (ICD) is increased. The joint forms an open angle laterally (JLCA).

Treatment modalities for coronal plane deformities

Observation

Patients with physiological varus or valgus knee (that is, who fall within the two standard deviations from the normal value for their age or within the second zone on the X-ray) require no treatment other than observation. Parents should be reassured that it is not a true deformity or disease, but a variant of normal lower limb alignment, which usually corrects spontaneously. These patients should be clinically evaluated every 3-6 months to monitor the deformity. Radiographic assessment should be

repeated if there is suspicion of clinical worsening [44]. Conservative treatment (e.g., shoe wedges or bracing) is not effective, is poorly tolerated, and is unnecessary in cases of physiological deviation [45-47].

Surgical treatment

It is generally accepted that a significant deformity that persists into preadolescence will not correct spontaneously. Physiological alignment of the lower limb is crucial for the symmetrical distribution of weight over the surfaces of the joints, especially the knee. Indeed, severe coronal malalignment has been linked to knee pain, altered gait, and occasionally patellofemoral problems. [48] Moreover, it can contribute to the development of osteoarthritis of the knee [49, 50]. Additionally, MA deviation in the lateral or medial compartment can lead to compression in the lateral or medial physis, thereby further delaying growth as a result of the Hueter-Volkman effect [51].

Preoperative planning

Preoperative planning could involve the malalignment test on a long-standing X-ray, as described by Paley and Tetsworth [42]: (1) Evaluation of MA and MAD. The first step is tracing the MA of the lower limb (e.g., from the center of the femoral head to the center of the ankle). The MA should pass through the center of the knee joint. If the MA axis does not go through the center of the knee joint, there is a MAD. Furthermore, the MA deviation can be classified into three zones as defined by Müller and Müller-Färber [52]. When the MAD exceeds the normal range (e.g., $> 8 \pm 7$ mm medial to the center of the knee joint line) [53] or the MA passes to the first zone [51, 52] a pathological malalignment is present and the following steps will determine the origin of the deformity; (2) Measurement of the mechanical lateral distal femur angle (n.v. = 87.5 ± 2.5): The lateral angle between the MAF and the line through the femoral condyles; (3) Measurement of the medial proximal tibial angle (n.v. = 87.5 ± 2.5): The medial angle between the MAT and the line through the tibial plateaus; (4) Measurement of the joint line convergence angle (n.v. = 0-2 degrees medial convergence): The angle between the femoral condyle and the tibial plateau joint line. This helps to evaluate any source from the ligament or capsular laxity or joint cartilage loss; (5) Ruling out a medial or lateral subluxation: The midpoints of the femur and the tibia should be aligned; and (6) Ruling out an intraarticular origin of the malalignment: The femoral condyles and the tibial plateaus should be aligned with respect to each other. A depressed or elevated femoral condyle or tibial plateau may indicate an intraarticular source of malorientation.

Figure 11: The malalignment test. The mechanical axis (MA) is traced from the center of the femoral head to the center of the ankle. The metaphyseal-diaphyseal angle (MAD) is calculated in millimeters (dotted lines in the image traced from center of knee and MA). If the MAD exceeds the threshold of normality,

it is necessary to find the source of the deformity. The mechanical lateral distal femur angle. Medial proximal tibial angle are evaluated. A: Varus; B: Normal; C: Valgus. MAD: Metaphyseal-diaphyseal angle; MPTA: Medial proximal tibial angle; mL DFA: Mechanical lateral distal femur angle.

The method described evaluates deformities near the knee. Deformities away from the knee should be investigated using the center of rotation of angulation (CORA) method and other angles such as the lateral proximal femur angle and the lateral distal tibial angle [54] whose description is beyond the scope of this article.

The authors stress that these measurements are only reliable if the X-ray projection is anteroposterior with the knee in the frontal plane, which is defined as the position where the patella is centered in the femoral condyles [55, 56]. This means that care must be taken to place the patient in the patella forward position, rather than in the feet forward position, as the latter is affected by tibial torsion and leads to incorrect measurement [55].

General indications

Surgical correction of coronal angular knee deformities is indicated if: (1) The MA falls within zone 2 and the patient is symptomatic; and (2) The MA is beyond zone 2 [51, 52]. If the deformity only involves the distal femur or the proximal tibia, the correction should only take place within the affected bone. If the deformity originates from both the femur and the tibia and is symmetrical, both bones should be treated. If, on the other hand, the deformity is asymmetrical, only the bone whose angle (LTFA and MTFA) deviates more than 5 degrees from the reference values should be treated [46, 57].

How to treat pathological genu varum and genu valgum

In growing children, the treatment strategies for coronal angular deformities around the knee are: (1) Hemiepiphyodesis; and (2) Osteotomy.

Osteotomy

The use of corrective osteotomy is indicated in patients close to or at skeletal maturity, or in those whose growth cartilages are not functional (e.g., after an infection, or in the presence of a physeal bar). The specifics of realignment osteotomies are beyond the scope of this article and have been reported in articles on this theme and summarized by Paley [53]. However, it is necessary to introduce the fundamental concept of the CORA, which can be summarized as the point of maximum deformity. When a corrective osteotomy is planned, the correction should be established close to the CORA to avoid introducing translation deformity [55]. In varus and valgus deformities of the knee, the CORA is adjacent to the articular surface and the physis. For this reason, osteotomy, whether of the distal femur or the proximal tibia, is generally not feasible in skeletally immature patients. This is to avoid iatrogenic damage

to the growth plate. Thus, in order to achieve realignment with corrective osteotomy, preoperative planning should take account of both the original angular deformity and any translation deformity introduced [55].

Correction through osteotomy can be acute, achieved using internal fixation devices (e.g., Kirschner wires, intramedullary nail, plates) or gradual, using an external fixator and distraction osteogenesis [58]. Gradual correction is attractive in cases of multiplanar deformity and modern hexapod systems are particularly useful in these situations [59].

The different types of osteotomy used to correct a deformity acutely are: [60] (1) Opening wedge; (2) Closing wedge; (3) Reverse wedge; and (4) Dome osteotomy. Acute deformity correction predisposes the patient to certain risks that should be taken into consideration during planning. Non-union or delayed union should be considered in opening wedge osteotomies greater than 20 degrees [83].

Neurovascular structures risk being stretched during acute correction. It is reported that the risk of injury to neurovascular structures is related to the magnitude of correction, but the limit is not well defined. Other factors that add to this risk are the site and type of osteotomy and the direction of correction. For example, a correction of a valgus to varus deformity of the knee by osteotomy of the distal femur or proximal tibia puts the common peroneal nerve (CPN) at risk, even if the correction is small (about 5 degrees) [62]. Conversely, a correction of a varus deformity releases the CPN. Further-more, the deep peroneal nerve (DPN), which passes under the intermuscular septum between the lateral and anterior compartment of the leg, is more at risk of injury than the superficial peroneal nerve (SPN) [53]. For the same reason, internal or external rotation osteotomies involving tensioning of the intermuscular septum create more risk for the DPN and less for the SPN. For these reasons, some authors suggest performing prophylactic peroneal nerve decompression before acute correction [62]. Additionally, the motor branch to the extensor hallucis longus is particularly at risk during fibular osteotomy [63].

Idiopathic pathological genu valgum and genu varum

It is generally established that growth plate modulation with staples or TBPs determines less morbidity than osteotomy. However, it is essential to evaluate the timing of epiphyodesis and to schedule close clinical monitoring to avoid overcorrection.

Post-traumatic

Trauma is one of the most frequent causes of pathological coronal deformity around the knee. The deformity may be a result of inadequate reduction or injury to the growth cartilage with a consequent alteration or arrest in growth (e.g., physeal bar). In the latter case, some authors report a high risk in cases of type 3 Salter-Harris (SH) fracture of the proximal tibia, whereas the type of SH fracture in the distal femur is poorly predictive. In

some cases, the physeal injury may be misdiagnosed if concomitant with another fracture of the femur or tibia. Therefore, some authors recommend knee X-rays in all patients with a traumatic lower limb injury [64].

Depending on the age of the patient, the location, the cause and the extent of the deformity, treatment may involve observation, physeal bar resection, epiphysiodesis, chondrodiastasis, or corrective osteotomy. Physeal bar resection consists of removing the bone bridging the metaphysis and the epiphysis and filling the gap with interposition material (e.g., fat, methyl methacrylate or polymeric silicone) to prevent the bony bar from reforming. This is indicated when there are at least 1 or 2 years of remaining growth, and when the bar involves < 50% of the growth plate. If a clinically unacceptable deformity is present at the time of physeal bar resection, an osteotomy or hemiepiphysiodesis is indicated to realign the lower limb. In fact, a successful physeal bar resection alone would not be able to fully correct the deformity [65].

A frequent form of post-traumatic knee valgus is tibia valga following fracture of the proximal metaphysis of the tibia, also known as Cozen's phenomenon. The exact etiology is still under debate. In these cases, the maximum magnitude of deformity is variable, and is reached approximately 12 months after injury. Parents should be advised of this eventuality and be informed that the deformity tends to resolve spontaneously within 2-4 years and only requires observation. Surgical treatment should be reserved for severe and symptomatic cases or for patients close to skeletal maturity with residual deformity [66]. Some authors report that, to prevent this deformity, the proximal tibial fracture should be treated with a varus-molded long-leg cast, although the efficacy of this procedure has been disputed in the literature [67]. Hemiplateau elevation (HE) is the treatment of choice for growing children with persistent deformity requiring surgery [68]. This must be performed within about three years of the trauma, since deformities tend to migrate distally at the level of the diaphysis during growth. Therefore, delayed HE could lead to a secondary "Z"-shaped deformity of the tibia (varus deformity proximal to the valgus deformity of the diaphysis). Corrective osteotomy should be avoided in growing children, as it can produce effects similar to the traumatic event itself and accentuate valgus deformity. It may be indicated in patients close to skeletal maturity with residual deformity [69].

Material and Methods

- o Study design: Prospective Analytical Study
- o Study area: Department of Orthopedics D Y Patil University School of Medicine & Hospital, Nerul, Navi Mumbai.
- o Study period: Research study was conducted from November 2022 to June 2024. Below is the work plan.
- o Sample size: 30 cases

o Inclusion criteria:

- All patients giving consent.
- Patients with distal femur deformity.
- Patient showing X-ray changes distal Femur fractures valgus deformity.
- Patients > 18 years or

o Exclusion criteria:

- Patient 80 years
- Patient not showing interest for long follow-up
- Patients not willing and not motivated for surgery and lifestyle changes postoperatively.

Method of Data collection:

After taking informed consent, 30 patients were recruited for our study. After informed written consent we analysed all patients with distal femur coronal plane deformity of distal femur in our hospital (all included patients were less than 80 years old). The demographic and radiological data of these patients was collected from the history presented by the patient. The aim of this study was correction of the coronal plane deformity of the distal femur using distal femoral nail. Deformities of the distal femur may be due to infection, congenital limb deficiencies, metabolic disorders and idiopathic causes. When combined with malalignment of the lower extremity axis, compartmental cartilage damage and knee osteoarthritis may develop. Therefore, realignment osteotomy of the distal femur is an ideal option to preserve the joint deformed into valgus position.

Various osteotomy techniques and fixation methods have been used to correct distal femoral deformities. The closed-wedge technique, with the fixation of an angled blade plate, has been a common procedure in distal femur osteotomy. The technical complexity and wide surgical dissection, however, contribute to high rates of complications, such as non-union, inaccurate correction of the deformity, plate irritation, superficial infection or risk of osteomyelitis loss of correction, as well as revision surgery. Recently, open-wedge osteotomy with an improved plate design has been attempted that makes it easier to correct the mechanical axis (MA) and adjust the amount of wedge opening intraoperatively. As healing time of the open wedge is expected to be longer, inferior mechanical stability at the osteotomy site is of great concern with the use of short plate.

For these reasons, we introduced a technique using a long locking distal femoral nail, as performed in acute coronal plane deformity of the distal femur, with the concept of minimally invasive osteosynthesis by intramedullary nail assistance. We hypothesized that the results and complication rate would be better than previous techniques of distal femur osteotomy. The purpose of this study was to describe the surgical procedure for correction and to document the outcome after patients underwent the newer technique of distal femoral coronal plane

deformity correction with distal femoral nail.

Parameter that were evaluated at discharge and follow-up at 3 months and 6 months:

- Width of medial joint space
- Joint line convergence angle (JLCA)
- Posterior tibial slope (PTS)
- Kellgren-Lawrence (KL) grade
- Medial proximal tibial angle (MPTA)
- Lateral distal femoral angle (LDFA)
- Time for union
- Lysholm Score

Lysholm knee scoring scale

SECTION 1 - LIMP

- I have no limp when I walk. (5)
- I have a slight or periodical limp when I walk. (3)
- I have a severe and constant limp when I walk. (0)

SECTION 2 - Using cane or crutches

- I do not use a cane or crutches. (5)
- I use a cane or crutches with some weight-bearing. (2)
- Putting weight on my hurt leg is impossible. (0)

SECTION 3 - Locking sensation in the knee

- I have no locking and no catching sensation in my knee. (15)
- I have catching sensation but no locking sensation in my knee. (10)
- My knee locks occasionally. (6)
- My knee locks frequently. (2)
- My knee feels locked at this moment. (0)

SECTION 4 - Giving way sensation from the knee

- My knee gives way. (25)
- My knee rarely gives way, only during athletics or vigorous activity. (20)
- My knee frequently gives way during athletics or other vigorous activities. In turn I am unable to participate in these activities. (15)
- My knee frequently gives way during daily activities. (10)
- My knee often gives way during daily activities. (5)
- My knee gives way every step I take. (0)

SECTION 5 – PAIN

- I have no pain in my knee. (25)
- I have intermittent or slight pain in my knee during vigorous activities. (20)
- I have marked pain in my knee during vigorous activities. (15)
- I have marked pain in my knee during or after walking more than 1 mile. (10)
- I have marked pain in my knee during or after walking less than 1 mile. (5)
- I have constant pain in my knee. (0)

SECTION 6 – SWELLING

- I have swelling in my knee. (10)
- I have swelling in my knee only after vigorous activities. (6)
- I have swelling in my knee after ordinary activities. (2)
- I have swelling constantly in my knee. (0)

SECTION 7 – CLIMBING STAIRS

- I have no problems climbing stairs. (10)
- I have slight problems climbing stairs. (6)
- I can climb stairs only one at a time. (2)
- Climbing stairs is impossible for me. (0)

SECTION 8 – SQUATTING

- I have no problems squatting. (5)
- I have slight problems squatting. (4)
- I cannot squat beyond a 90deg. Bend in my knee. (1)
- Squatting is impossible because of my knee. (0)

Total: _____/100 [3 months]

Total: _____/100 [6 months]

Results

The present prospective analytical study was conducted among 30 patients with distal femur deformity presenting to department of orthopedics in Dr D Y Patil Hospital, Nerul, Navi Mumbai for a period of two years to study the correction of coronal plane deformity of distal femur using distal femoral nail. Following are the study findings:

Distribution of patients according to age

This shows the age distribution of the 30 patients in the study. The majority of patients (63.3%) were between 20-40 years old, followed by 30% in the 41-60 age group, and only 6.7% in the 18-20 age group. This suggests that distal femur deformities in this study were most common in young to middle-aged adults.

Distribution of patient according to gender

The gender distribution of patients was fairly balanced, with a slight majority of females (53.3%) compared to males (46.7%). This indicates that the condition affects both genders relatively equally in this study population.

Distribution of patient according to Body Mass Index

This categorizes patients based on their Body Mass Index (BMI). The largest group (36.7%) had a normal BMI (18.5-24.9), followed by overweight patients (26.7%), obese patients (23.3%), and underweight patients (13.3%). This distribution suggests that while the condition affects people of all body types, there might be a slight tendency towards higher BMI categories.

Distribution of patient according to malunion/deformity

The most common mode of injury was malunion/deformity (40%), followed by equal proportions of Road Traffic Accidents (RTA) and sports injuries (30% each). This indicates that pre-existing conditions or improper healing of previous injuries may be a significant factor in distal femur deformities.

Distribution of patient according to symptoms

This breaks down various symptoms experienced by patients. In our study 40% reported severe pain, while 20% each reported mild, unbearable, or no pain. Whereas 36.7% had no swelling,

30% had mild swelling, 23.3% moderate, and 10% severe swelling. There were 26.7% of patients who experienced a "give away sensation." Regarding function, 63.3% had no limitation in daily activities, while 36.7% could not perform daily activities. These results suggest a wide range of symptom severity among patients.

Distribution of patient according to imaging findings

This compares pre-operative and post-operative measurements. The width of medial joint space increased from 2.9 ± 1.5 to 27.1 ± 6.7 . Joint line convergence angle decreased from 6.5 ± 2.5 to 4.7 ± 2.7 . Posterior tibial slope remained relatively stable (10.8 ± 2.9 to 10.8 ± 3). Medial proximal tibial angle and lateral distal femoral angle both increased slightly. These changes indicate successful surgical correction of the deformity.

Distribution of patients according time for union

The average time for union was 11.4 ± 3.4 weeks, with a minimum of 6 weeks and a maximum of 16 weeks. This suggests a relatively quick healing process for most patients.

Distribution of patients according to range of movements

Post-operative knee flexion averaged 109.3 ± 11.8 degrees (range 90-160), while knee extension averaged 0.07 ± 3.4 degrees (range -5 to 5). This indicates good functional outcomes in terms of knee mobility.

Distribution of patients according to functional outcome (Lysholm scores)

This shows a significant improvement in functional outcomes. Pre-operatively, all patients (100%) had poor scores. Post-operatively, 56.7% had fair outcomes, 16.7% good, 13.3% excellent, and only 13.3% remained poor. This demonstrates the effectiveness of the surgical intervention in improving patient function.

Distribution of patient according to complications

Complications were relatively low in our study with Knee stiffness in 6.7% cases, Infection in 3.3%, Nail displacement in 3.3%, Mal union in 3.3%. No cases of non-union were reported. This suggests that the procedure is generally safe with a low complication rate.

Association of functional outcome with age

This cross-tabulation shows the relationship between age and functional outcomes. The 20-40 age group had the most diverse outcomes, with representations in all categories. The 18-20 age group had only good and excellent outcomes. The 41-60 age group had only poor and fair outcomes. However, the p-value of 0.133 suggests that this association is not statistically significant.

Association of functional outcome with BMI

This examines the relationship between BMI and functional outcomes. Underweight patients had either fair or excellent outcomes. Normal BMI patients were represented in all outcome categories. Overweight patients had poor to good outcomes, but none in the excellent category. Obese patients had outcomes ranging from poor to good, with the highest proportion in the good category. The p-value of 0.205 indicates that this association is not statistically significant.

Discussion

Distal femoral deformities present a significant challenge in orthopedic surgery, often resulting in pain, functional limitations, and altered biomechanics of the knee joint. The correction of coronal plane deformities in the distal femur is crucial for restoring proper alignment and improving patient outcomes. This study aimed to evaluate the efficacy of using distal femoral nails in correcting such deformities. The following discussion will analyze our findings in the context of existing literature, highlighting the similarities and differences in patient demographics, surgical outcomes, and complications.

Demographics and Patient Characteristics:

Our study included 30 patients with a predominant age group of 20-40 years (63.3%). The gender distribution in our study was relatively balanced, with 16 females and 14 males.

The BMI distribution in our study showed that 36.7% of patients had a normal BMI (18.5-24.9), while 50% were either overweight or obese. This finding is particularly relevant as Ekeland et al. [70] reported that higher BMI is associated with increased risk of complications in distal femoral osteotomies.

Mode of Injury and Symptoms:

In our study, malunion/deformity was the most common mode of injury (40%), followed by road traffic accidents (RTA) and sports injuries (30% each). These findings highlight the diverse etiologies of distal femoral deformities.

Regarding symptoms, 80% of our patients reported pain ranging from mild to unbearable, with 40% experiencing severe pain. This high prevalence of pain aligns with the observations of Wylie et al. [71], who emphasized pain as a primary indication for surgical intervention in distal femoral deformities.

Imaging Findings and Surgical Outcomes:

Our study demonstrated significant improvements in radiographic parameters post-operatively. The mean width of the medial joint space increased from 2.9 ± 1.5 mm to 27.1 ± 6.7 mm, indicating successful correction of the deformity. This substantial improvement is comparable to the findings of Jacobi et al. [72], who reported significant increases in joint space following distal femoral osteotomy.

The mean time for union in our study was 11.4 ± 3.4 weeks, which is slightly shorter than the average of 14 weeks reported by Brinkman et al. [73] in their study of distal femoral osteotomies. This difference might be attributed to the use of intramedullary nailing in our study, which potentially provides better stability and promotes faster healing.

Functional Outcomes:

The Lysholm scores in our study showed remarkable improvement, with 86.7% of patients achieving fair to excellent scores post-operatively, compared to 100% poor scores pre-operatively. This significant functional improvement is consistent with the findings of Saithna et al. [74], who reported substantial increases in Lysholm scores following distal femoral osteotomy.

Our study found no significant association between age and functional outcomes ($p > 0.05$), which contrasts with the findings of Ekland et al. [70], who reported better outcomes in younger patients. This discrepancy might be due to differences in sample size or the specific surgical technique used.

Complications:

The complication rate in our study was relatively low, with infection, nail displacement, and knee stiffness each occurring in 3.3% of cases, and malunion in 3.3% of cases. Notably, we observed no cases of non-union. These rates are comparable to those reported by Khakharia et al. [74], who found similar complication rates in their series of distal femoral osteotomies. The absence of non-union in our study is particularly encouraging and may be attributed to the stability provided by the distal femoral nail. This finding supports the observations of Brinkman et al. [73], who emphasized the importance of stable fixation in achieving successful union.

In conclusion, our study demonstrates that the use of distal femoral nails for correcting coronal plane deformities of the distal femur is an effective and safe procedure. The significant improvements in radiographic parameters, functional outcomes, and low complication rates are consistent with existing literature on distal femoral osteotomies. Future studies with larger sample sizes and longer follow-up periods may provide further insights into the long-term outcomes and potential advantages of this technique over other methods of fixation.

Conclusion

This prospective study on the correction of coronal plane deformities of the distal femur using distal femoral nails demonstrates promising results in terms of both radiographic and functional outcomes. The procedure proved effective across various age groups and BMI categories, with significant improvements in joint space width, alignment angles, and patient-reported functional scores.

The use of distal femoral nails resulted in satisfactory union

rates, with an average time to union of 11.4 weeks. This relatively quick healing time, combined with the substantial improvements in knee range of motion, suggests that the technique provides adequate stability for early rehabilitation and functional recovery.

The low complication rate observed in this study, particularly the absence of non-union cases, further supports the safety and efficacy of this approach. However, the occurrence of minor complications such as infection, nail displacement, and knee stiffness highlights the need for meticulous surgical technique and appropriate post-operative management.

While the study shows encouraging results, it's important to note that long-term follow-up would be beneficial to assess the durability of the correction and the potential development of late complications. Additionally, future comparative studies with other fixation methods could further elucidate the specific advantages of distal femoral nails in managing these challenging deformities.

In conclusion, the use of distal femoral nails for correcting coronal plane deformities of the distal femur appears to be a viable and effective treatment option, offering good functional outcomes and a low complication rate. This technique may be particularly valuable in cases where stability and early mobilization are crucial for patient recovery.

References

- Sharma L, Song J, Felson DT, Cahue S, Shamiyeh E, Dunlop DD. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. *JAMA*. 2001 Jul 11;286(2):188-95.
- Janakiraman N, Teichtahl AJ, Wluka AE, et al. Static knee alignment is associated with the risk of unicompartmental knee cartilage defects. *Orthop Res*. 2008 Feb;26(2):225e230.
- Zhai G, Ding C, Cicuttini F, Jones G. A longitudinal study of the association between knee alignment and change in cartilage volume and chondral defects in a largely non-osteoarthritic population. *J Rheumatol*. 2007 Jan;34(1):181e186.
- Tetsworth K, Paley D. Malalignment and degenerative arthropathy. *Orthop Clin North Am*. 1994;25(3):367e377.
- Amendola A, Bonasia DE. Results of high tibial osteotomy: review of the literature. *Int Orthop*. 2010 Apr;34(2):155-60.
- Staubli AE, De Simoni C, Babst R, Lobenhoffer P. TomoFix: a new LCP-concept for open wedge osteotomy of the medial proximal tibia--early results in 92 cases. *Injury*. 2003 Nov;34 Suppl 2:B55-62.
- Miller BS, Downie B, McDonough EB, Wojtys EM. Complications after medial opening wedge high tibial osteotomy. *Arthroscopy*. 2009 May;25(5):639-46.
- Yilmaz G, Oto M, Thabet AM, et al. Correction of lower extremity angular deformities in skeletal dysplasia with hemiepiphysiodesis: a preliminary report. *J Pediatr Orthop*. 2014 Apr-May;34(3):336e345.

9. Brinkman JM, Lobenhoffer P, Agneskirchner JD, Staubli AE, Wymenga AB, van Heerwaarden RJ. Osteotomies around the knee: patient selection, stability of fixation and bone healing in high tibial osteotomies. *J Bone Joint Surg Br.* 2008 Dec;90(12):1548-57.
10. Woodacre T, Ricketts M, Evans JT, Pavlou G, Schranz P, Hockings M, Toms A. Complications associated with opening wedge high tibial osteotomy - A review of the literature and of 15 years of experience. *Knee.* 2016 Dec;23(6):276-82.
11. Boese CK, Dargel J, Oppermann J, Eysel P, Scheyerer MJ, Bredow J, Lechler P. The femoral neck-shaft angle on plain radiographs: a systematic review. *Skeletal Radiol.* 2016 Jan;45(1):19-28.
12. Reynolds A. The fractured femur. *Radiol Technol.* 2013 Jan-Feb;84(3):273-91; quiz p.292-4.
13. Li M, Cole PA. Anatomical considerations in adult femoral neck fractures: how anatomy influences the treatment issues? *Injury.* 2015 Mar;46(3):453-8.
14. Carballido-Gamio J, Nicoletta DP. Computational anatomy in the study of bone structure. *Curr Osteoporos Rep.* 2013 Sep;11(3):237-45.
15. Wagner FV, Negrão JR, Campos J, Ward SR, Haghighi P, Trudell DJ, Resnick D. Capsular ligaments of the hip: anatomic, histologic, and positional study in cadaveric specimens with MR arthrography. *Radiology.* 2012 Apr;263(1):189-98.
16. Fernandez MA, Griffin XL, Costa ML. Management of hip fracture. *Br Med Bull.* 2015 Sep;115(1):165-72.
17. van Arkel RJ, Amis AA, Jeffers JR. The envelope of passive motion allowed by the capsular ligaments of the hip. *J Biomech.* 2015 Nov 05;48(14):3803-9.
18. Ehlinger M, Ducrot G, Adam P, Bonnomet F. Distal femur fractures. Surgical techniques and a review of the literature. *Orthop Traumatol Surg Res.* 2013 May;99(3):353-60.
19. Elshazzly M, Lopez MJ, Reddy V, Caban O. StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Apr 3, 2023. Embryology, Central Nervous System.
20. Lazaro LE, Klinger CE, Sculco PK, Helfet DL, Lorch DG. The terminal branches of the medial femoral circumflex artery: the arterial supply of the femoral head. *Bone Joint J.* 2015 Sep;97-B(9):1204-13.
21. Nasr AY, Badawoud MH, Al-Hayani AA, Hussein AM. Origin of profunda femoris artery and its circumflex femoral branches: anatomical variations and clinical significance. *Folia Morphol (Warsz).* 2014 Feb;73(1):58-67.
22. Vuksanović-Božarić A, Abramović M, Vučković L, Golubović M, Vukčević B, Radunović M. Clinical significance of understanding lateral and medial circumflex femoral artery origin variability. *Anat Sci Int.* 2018 Sep;93(4):449-455.
23. Burghardt RD, Siebenlist S, Döbele S, Lucke M, Stöckle U. Compartment syndrome of the thigh. A case report with delayed onset after stable pelvic ring fracture and chronic anticoagulation therapy. *BMC Geriatr.* 2010 Jul 27;10:51.
24. Hernando MF, Cerezal L, Pérez-Carro L, Abascal F, Canga A. Deep gluteal syndrome: anatomy, imaging, and management of sciatic nerve entrapments in the subgluteal space. *Skeletal Radiol.* 2015 Jul;44(7):919-34.
25. Marques Luís N, Varatojo R. Radiological assessment of lower limb alignment. *EFORT Open Rev.* 2021 Jun 28;6(6):487-494.
26. Sheehy L. Radiographic assessment of leg alignment and grading of knee osteoarthritis: a critical review. *World J Rheumatol* 2015;5:69.
27. Zampogna B, Vasta S, Amendola A, et al.. Assessing lower limb alignment: comparison of standard knee Xray vs long leg view. *Iowa Orthop J* 2015;35:49-54.
28. Sheehy L, Felson D, Zhang Y, et al.. Does measurement of the anatomic axis consistently predict hip-knee-ankle angle (HKA) for knee alignment studies in osteoarthritis? Analysis of long limb radiographs from the multicenter osteoarthritis (MOST) study. *Osteoarthritis Cartilage* 2011;19:58-64.
29. Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. *J Bone Joint Surg Am* 1987;69:745-749.
30. Yoshioka Y, Siu D, Cooke TD. The anatomy and functional axes of the femur. *J Bone Joint Surg Am* 1987;69:873-880.
31. Krackow K. The measurement and analysis of axial deformity at the knee. Mahwah, NJ: Homer Stryker Center, 2008.
32. Krackow K. Preoperative assessment: axial and rotational alignment an X-ray analysis. In: Krackow K, The technique of total knee arthroplasty. St. Louis: The CV Mosby Company, 1990.
33. Chao EY, Neluheni EV, Hsu RW, Paley D. Biomechanics of malalignment. *Orthop Clin North Am* 1994;25:379-386.
34. Lobenhoffer P, van Heerwaarden R, Staubli A, Jakob R, Galla M, Agneskirchner J. Osteotomies around the knee, indications - planning - surgical techniques using plate fixators. Davos: Switzerland: AO Publishing, Thieme Verlag, 2008.
35. Sutherland DH, Olshen R, Cooper L, Woo SL. The development of mature gait. *J Bone Joint Surg Am.* 1980 Apr;62(3):336-53.
36. Espandar R, Mortazavi SM, Baghdadi T. Angular deformities of the lower limb in children. *Asian J Sports Med.* 2010 Mar;1(1):46-53.
37. Heath CH, Staheli LT. Normal limits of knee angle in white children--genu varum and genu valgum. *J Pediatr Orthop.* 1993 Mar-Apr;13(2):259-62.
38. Patel M, Nelson R. Genu Valgum. [Updated 2023 May 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK559244/>
39. COZEN L. Fracture of the proximal portion of the tibia in children followed by valgus deformity. *Surg Gynecol Obstet.* 1953 Aug;97(2):183-8.
40. Burton A, Hennrikus W. Cozen's phenomenon revisited. *J Pediatr Orthop B.* 2016 Nov;25(6):551-555.

41. Salenius P, Vankka E. The development of the tibiofemoral angle in children. *J Bone Joint Surg Am.* 1975 Mar;57(2):259-61.
42. Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of uniapical angular deformities of the tibia or femur. *Clin Orthop Relat Res.* 1992 Jul;(280):48-64.
43. Paley D. Radiographic assessment of lower limb deformities. In: Paley D, Principles of deformity correction. Berlin Heidelberg: Springer, 2002:31-60.
44. White GR, Mencio GA. Genu Valgum in Children: Diagnostic and Therapeutic Alternatives. *J Am Acad Orthop Surg.* 1995;3:275-283.
45. Brooks WC, Gross RH. Genu Varum in Children: Diagnosis and Treatment. *J Am Acad Orthop Surg.* 1995;3:326-335.
46. Staheli LT. Practice of Pediatric Orthopaedic. In: Mosca V. Lower Limb. Seattle: Lippincott Williams & Wilkins, 2006: 77-104.
47. Gupta P, Gupta V, Patil B, Verma V. Angular deformities of lower limb in children: Correction for whom, when and how? *J Clin Orthop Trauma.* 2020;11:196-201.
48. Boero S, Michelis MB, Riganti S. Use of the eight-Plate for angular correction of knee deformities due to idiopathic and pathologic physis: initiating treatment according to etiology. *J Child Orthop.* 2011;5:209-216.
49. Saran N, Rathjen KE. Guided growth for the correction of pediatric lower limb angular deformity. *J Am Acad Orthop Surg.* 2010;18:528-536.
50. Tetsworth K, Paley D. Malalignment and degenerative arthropathy. *Orthop Clin North Am.* 1994;25:367-377.
51. Stevens PM, Maguire M, Dales MD, Robins AJ. Physeal stapling for idiopathic genu valgum. *J Pediatr Orthop.* 1999;19:645-649.
52. Hierholzer K G, Müller H. Corrective Osteotomies of the Lower Extremity after Trauma. In: Müller KH, Müller-Färber J. Indications, Localization and Planning of Posttraumatic Osteotomies about the Knee. Heidelberg: Springer, 1985: 195-223.
53. Paley D. Principles of Deformity Correction. In: Paley D. Normal Lower Limb Alignment and Joint Orientation. Heidelberg: Springer, 2002: 1-18.
54. Paley D. Principles of Deformity Correction. Heidelberg: Springer, 2002.
55. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhava A. Deformity planning for frontal and sagittal plane corrective osteotomies. *Orthop Clin North Am.* 1994;25:425-465.
56. Wright JG, Treble N, Feinstein AR. Measurement of lower limb alignment using long radiographs. *J Bone Joint Surg Br.* 1991;73:721-723.
57. Sabharwal S. Pediatric Lower Limb Deformities. In: Miller ML, Eric Gordon J. Decision making in lower extremity deformity correction. New York: Springer, 2016: 37-50.
58. Paley D. Principles of Deformity Correction. In: Length Considerations: Gradual Versus Acute Correction of Deformities. Heidelberg: Springer, 2002: 269-289.
59. Riganti S, Nasto LA, Mannino S, Marrè Brunenghi G, Boero S. Correction of complex lower limb angular deformities with or without length discrepancy in children using the TL-HEX hexapod system: comparison of clinical and radiographical results. *J Pediatr Orthop B.* 2019;28:214-220.
60. Smith JO, Wilson AJ, Thomas NP. Osteotomy around the knee: evolution, principles and results. *Knee Surg Sports Traumatol Arthrosc.* 2013;21:3-22.
61. Kamegaya M, Shinohara Y, Shinada Y. Limb lengthening and correction of angulation deformity: immediate correction by using a unilateral fixator. *J Pediatr Orthop.* 1996;16:477-479.
62. Nogueira MP, Paley D. Prophylactic and Therapeutic Peroneal Nerve Decompression for Deformity Correction and Lengthening. *Oper Tech Orthop.* 2011;21:180-183.
63. Tunggal JA, Higgins GA, Waddell JP. Complications of closing wedge high tibial osteotomy. *Int Orthop.* 2010;34:255-261.
64. Hresko MT, Kasser JR. Physeal arrest about the knee associated with non-physeal fractures in the lower extremity. *J Bone Joint Surg Am.* 1989;71:698-703.
65. Dabash S, Prabhakar G, Potter E, Thabet AM, Abdelgawad A, Heinrich S. Management of growth arrest: Current practice and future directions. *J Clin Orthop Trauma.* 2018;9:S58-S66.
66. Papamerouriou YM, Tsoumpos P, Tagaris G, Christodoulou G. Does Cozen's phenomenon warrant surgical intervention? *J Child Orthop.* 2020;14:213-220.
67. Burton A, Hennrikus W. Cozen's phenomenon revisited. *J Pediatr Orthop B.* 2016;25:551-555.
68. Morin M, Klatt J, Stevens PM. Cozen's deformity: resolved by guided growth. *Strategies Trauma Limb Reconstr.* 2018;13:87-93.
69. Herring JA. Tachdjian's Pediatric Orthopaedics: From the Texas Scottish Rite Hospital for Children. 5th ed. In: Johnston CE, Young M. Disorders of the Leg. Philadelphia: Elsevier, 2013: 713-761.
70. Ekeland A, Nerhus TK, Dimmen S, et al. Good functional results following high tibial opening-wedge osteotomy of knees with medial osteoarthritis. *Knee.* 2017;24(2):380-389.
71. Wylie JD, Jones DL, Hartley MK, et al. Distal Femoral Osteotomy for the Valgus Knee: Medial Closing Wedge Versus Lateral Opening Wedge: A Systematic Review. *Arthroscopy.* 2016;32(10):2141-2147.
72. Jacobi M, Wahl P, Bouaicha S, et al. Distal femoral varus osteotomy: problems associated with the lateral open-wedge technique. *Arch Orthop Trauma Surg.* 2011;131(6):725-728.
73. Brinkman JM, Lobenhoffer P, Agneskirchner JD, et al. Osteotomies around the knee: patient selection, stability of fixation and bone healing in high tibial osteotomies. *J Bone Joint Surg Br.* 2008;90(12):1548-1557.
74. Saithna A, Kundra R, Modi CS, et al. Distal femoral varus

osteotomy for lateral compartment osteoarthritis of the knee. *Open Orthop J.* 2012;6:313-319. **Quadricepsplasty for Contracture During Femoral Lengthening.** *Clin Orthop Relat Res.* 2009;467(11):2911-2917.
75. Khakharia S, Fragomen AT, Rozbruch SR. Limited

Conflict of Interest: Nil

Source of Support: None

Institute Where Research was Conducted: Department of Orthopedics, D Y Patil University School of Medicine & Hospital, Nerul, Navi Mumbai.

University Affiliation: D Y Patil University, Nerul.

Year of Acceptance of Thesis: 2024

How to Cite this Article: Saheta A, Kale S, Chalak A. Evaluation of Safety and Efficacy of Distal Nail Implant for Correction of Coronal Plane Deformity: A Prospective Observational Study. *Journal Medical Thesis* 2024 January-June; 10(1):30-45.