Case Report

Surgical and Medical Management of Deformity and Non-union with Implant failure of Femur in OI Type III

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Abstract

Purpose: Osteogenesis imperfecta (OI) is characterized by increased bone fragility and susceptibility for fracture because of the mutation of genes. A few studies are there for treatment modalities of non-union femur fractures in children with OI. This study on adult OI patients aims to give insight into non-unions and their best treatment reporting the surgical modification by using a humeral nail for femoral fixation options to avert non-union. Best implant in the adolescent OI patients for the surgical reconstruction of the femur for correction of deformity healing non-union.

Methods: This is a retrospective, descriptive study of the OI type III fracture non-union and its treatment modality.

Conclusions: In Adolescent OI patients with the rare percentage of non-union with deformity with implant failure of the femur was fixed with Humerus nail having stable fixation deformity correction by both osteotomy rotational translational and conversion of non-union to union with a better result.

Keywords: Osteogenesis imperfecta (OI), TENS Tensile Elastic Nail System, Adolescent, Humeral nail, Femoral bowing deformity

Background

Osteogenesis imperfecta (OI) is a rare hereditary connective tissue disorder with the common clinical presentation of excessive bone fragility caused by mutations in collagen multiple fractures, deformity with extraskeletal manifestations variable occurrence of blue sclerae, dentinogenesis imperfecta, hyperlaxity, hearing loss, short stature aortic root dilatation, macrocephaly, and basilar invagination [1].

Osteogenesis imperfect known as Lobstein–Vrolik disease or brittle bone disease is a connective tissue dysplasia heterogeneous inherited phenotypically and genotypically exists in1:10,000–1:20,000 new-born. Commonly the disease is inherited in an autosomal dominant, but there are rare autosomal recessive and X-linked forms of the disease also. Mutation within theCOL1A1and COL1A2 genesis reason for a disease that is responsible for the synthesis of type I collagen. Intercellular substances in the skin, bones, and ligaments main protein type I collagen bring about one-third of the body's total protein. The collagen is a triple helix, consisting of two pro-α1 chains and one pro-α2chain. Mutations curtail the modified α-chain folding disrupting its structure, impaired exocytosis, and cross-linking of collagen molecules into fibrils, which might result in apoptosis

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activation with glycine replacing large amino acid-qualitative defect. The bone tissue is violated with bone re-modeling in mild cases collagen is reduced to half - quantitative defect. Increased number of osteoclasts and osteoblasts increases accelerated bone re-modeling processes in severe OI cases [2, 3, 4, 5].

OI research is redefined by the discovery of recent genes realization changes in the bone formation process that do not seem to be related to collagen, but with impaired bone mineralization, osteoblast differentiation, and functioning. With an autosomal dominant inheritance first non–collagen related mutation seen in IFITM5 was discovered in 2000. Hypertrophic callus formation and interosseous membrane ossification were characteristic. First mutation with an autosomal recessive mode of inheritance within the CRTAP gene described by 2006, Morello et al. [6, 7, 8, 9].

Classification

D.O. Sillence proposed the first OI classification in 1978. It was based on clinical and radiological data, as well as on the inheritance pattern. The course of the disease can vary greatly–from mild to perinatally fatal outcomes. The types are distributed based on disease severity as follows: I < IV<III <II [10, 11].

Type I is the mildest form, which is characterized by frequent fractures, blue sclerae, and hearing impairment. Fractures appear at an early age when the child starts walking; their frequency decreases after growth completion. The stature is often normal. The occurrence of limb deformities and imperfect dentinogenesis is rare.

Type II is the perinatally fatal form with the most severe signs, providing that the child survives at birth. Multiple fractures are detected at the intrauterine stage. Limbs are usually short, with arcuate deformations. The sclerae are blue or gray. Death is caused by respiratory failure due to small chest, rib fractures, and pneumonia caused by collagen-associated lung tissue abnormality.

Type III is characterized by progressive limb deformities. Over their lifetimes, the patients experience hundreds of fractures. The face shape is often triangular, with frontal tubers; the sclera is blue or gray. Dentinogenesis imperfecta, vertebral body compression, scoliosis, and platibasia are also noted. The stature is very short.

Type IV is characterized by moderate severity. The incidence of fractures numbers in the tens; many patients are able to walk. This type is characterized by dentinogenesis imperfecta, basilar depression, hearing impairment, and growth variability.

Type V is also characterized by frequent fractures. However, the peculiarity consists in the hypertrophic callus formation and interosseous membrane ossification on the forearm.

Genetic counseling is important for families with members affected by OI, who wish to have children. The feasible prenatal diagnosis is by fetal ultrasound, originating with a the14th-18th week of pregnancy in severe form. During ultrasound diagnosis, the less severe form can be freely unnoticed. During the first trimester of pregnancy, the biopsy of the chorionic villosities, genetic and molecular biology tests can establish the diagnosis of OI, giving the parents the option of terminating the pregnancy if severe forms are discovered [12, 13].

In OI patients' clinical manifestations is a wide spectrum and could vary from destructive forms in the perinatal period to the subtle forms with issues of excessive fragility, frequent fractures, progressive deformity of long bones, and impaired ambulation. In Femur develop deformity anterior/varus angulation and retroversion tibia develop anterolateral bowing and the humerus varus angulation and/or internal rotation deformity. Diagnostic information and to guide treatment DEXA Dual-energy X-ray absorptiometry is very helpful [14].

The treatment of OI requires a multidisciplinary approach including medical treatment, such as using bisphosphonates therapy to lessen long bone fractures rate and to strengthen bone mineral density. The surgical treatment for fracture fixation or deformity correction with orthotic treatment to enhance functional results. The goal of surgery is to revive mechanical alignment, reduce fracture incidence, and promote ambulation [15, 16].

Bisphosphonates specific inhibitors to osteoclast-mediated bone resorption are the mainstay of pharmacologic treatment in OI. [17] In a recent Cochrane review of fourteen studies, bisphosphonates were shown to improve bone density after treatment (Dwan, 2016) [18, 20]. The clinical fractures are reduced with increased BMD (Gatti, 2004). Denosumab an anti-RANKL (receptor activator of nuclear factor kappa-B ligand) antibody acts on osteoclasts to suppress bone resorption increase bone density [21]. Teriparatide a PTH analog (a recombinant human parathyroid hormone that induces anabolism in bone, significantly increased bone mineral density in adults with OI type I, but it was not as effective in moderate and severe forms of OI [19].

Sclerostin inhibitory antibody anabolic agent increased bone

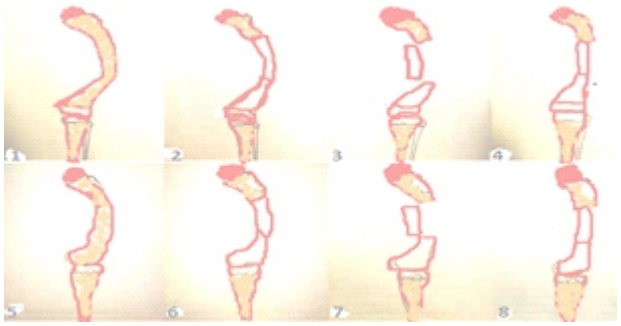

Figure 1: Osteotomy

Parameter	Hb g/dL	Vit D	TSH mU/L	T3 pg/mL	T4 ng/dL	AlkPhos U/L	Dexa Scan T score
Normal Value	12-15	100 mcg	0.8 to 6.0	2.73 to 4.69	1.0 to 2.1	42-362	+ 1 to – 1 Normal Bone Density – 1 and – 2.5 Osteopenia – 2.5 or less Osteoporosis
Reports	6.6	22.4	1.68	5.9	16.26	400	- 4.5

Table 1: Preoperative Blood Reports

formation, decreased bone resorption, and increased bone mineral density Transforming growth factor-beta inhibition Progenitor cell therapy stem cells are under trial [22, 23, 24].

Preposition surgical management of OI, the target is maintained reinstate bone axis decrease the incidence of fracture and avert bowing of bone. The preferred implant for long bones in OI patients is an Intra Medullary rod load sharing device because it is not complicated with the stress riser effect, protects the whole length of a long bone, and does not shield the stress from the bone tissue it protects, preventing osteopenia so better biomechanical property.

The plate is used less because of complications, such as bony resorption from stress shielding, implant failure, and subsequent fracture at the plate ends. Limb lengthening using an external fixator was theoretically possible in patients with type I OI, with complications of adjacent joint disfiguration due to increased joint pressure poor regenerated bone after implant removal [25].

In intramedullary implants, Static implants and telescopy nail is used as per the age of the patient. So, field procedure of multiple osteotomies and IM rod fixation a telescopic rod was devised by Bailey and Dubow back in 1963 with complications either from the device design or from the abnormal bone tissue. Bailey-Dubow rod was modified to Sheffield rod, improved the result by wiping out the device-oriented complications but damages to the distal femur and distal tibia still there. Then, the Fassier-Duval rod the next generation telescopic rod aid antegrade obturator insertion without arthrotomy of the distal joint, and distal articular cartilage of the long bone is not damaged. The corkscrew-tipped telescopic rod is also emerging. The Telescopic rod is a combination of a hollow sleeve and its obturator with the proximal end of a sleeve is docked at the proximal epiphysis although the distal end of an obturator at the distal epiphysis [26, 27, 28, 29, 30, 31].

In recent past few studies had noted that the small intramedullary IM interlocking nail, like a humeral nail, in adolescent patients can be used for femoral fixation due to the benefits of the entry point lateral to the tip of greater trochanter leading to escape iatrogenic vascular injury and Humerus interlock nail is of smaller diameter and shorter length than a conventional femoral nail which is appropriate for the small-sized adolescent femur. Therefore, in adolescent OI patients this humeral nail should be also useful and applicable for femoral fixation. This study intended to validate the result of adolescent OI patients with femoral deformity, fracture, and non-union treated with humeral nail fixation [39].

Augment fixation-Poor bone stock thin diaphysis in adolescents or adults with OI interferes with effective fixation and bone healing mechanism. Additional fixation is needed to reinforce IM rodding for osteotomy fixation, fracture management, osteosynthesis of delayed or nonunion of the OI long bone with a longer locking plate, and unicortical screw fixation. Another option to augment fixation of the long bone in OI cases with poor bone stock is the sandwich technique; around the circumference of the lesion, cortical allograft straps are applied [32].

Regarding Osteotomy, we used a rotational and translational osteotomy to redress its malalignment and femoral bowing, followed by fixation with a Humerus Nail The severe bowing at the coronal plane was changed into bowing in the sagittal plane. Appropriate realm is with the slight translation of the resected fragment, decreasing bowing degree. Use of drills and osteotome is preferred to minimize the risk of bone non-union minimizing soft-tissue stripping and avoiding the employment of power saws to create an osteotomy, as the friction and subsequent heat can cause osteonecrosis [33, 34].

pseudarthrosis develops in severely affected patients with impoverished management of fractures commonly at proximal and distal femur or humerus. It should be treated via rigid fixation and autogenous bone graft, with additional fixation that reinforces the IM rod and an allograft and which technique is also supportive [35].

Case Report

A10-year-old girl presented with deformity, swelling, pain, scar mark over the left thigh as a history narrated by a patient that operated on a fractured shaft of femur 9 months back fixed with TENS Tensile Elastic Nail System. After blood, radiological, molecular investigation it was confirmed OI type III. On clinical examination, the ROM of the hip knee ankle was passive possible. The neurovascular examination was normal. The main problem of our patient was the loss of capacity for independent walking and upright standing.

Standing anteroposterior (AP) full limb radiographs of affected

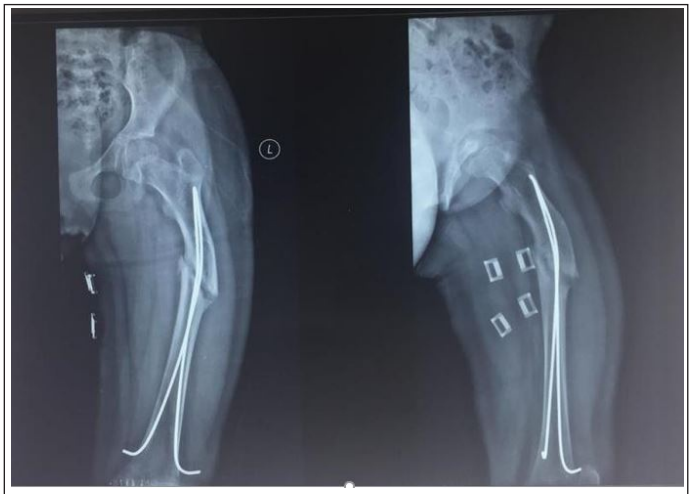

Figure 2: Preoperative X-ray, non-union femur with deformity

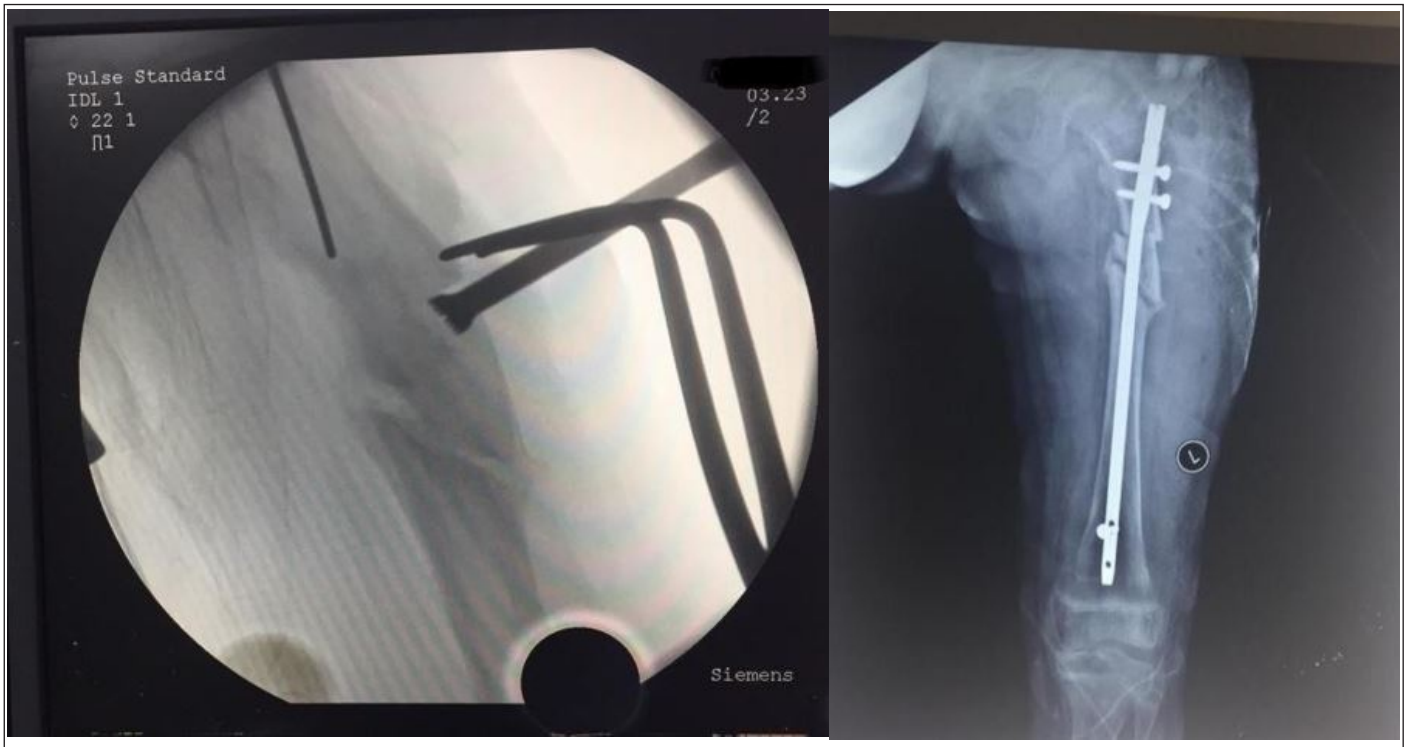

Figure 3: Intraoperative & Post Operative osteototomy

lower extremities were taken. Radiographs AP and lateral view show Left bowing and varus deformity non-union femur with the implant in situ with bending of implant, thickening of the cortical bone, and medullary canal narrowing. Dexa scan report suggested low bone density. Decreased bone mineral density may be associated with osteogenesis imperfecta, and DEXA helps detect low bone mineral density for risk of future and deciding management.

Planned for surgery initial Implant was removed and two-level osteotomy of femur done at subtrochanteric region transverse osteotomy correct bowing and non-union site used as oblique osteotomy to refreshened fracture ends then fixation with humerus nail. We decided to use humeral Intra Medullary nail for femoral osteotomy stabilization in this case due to two reasons. Firstly, the humeral nail was the interlocking nail that was available in a smaller size and shorter length than the conventional femoral nail. Thus, the humeral nail would be better in biomechanical property than TENS Tensile Elastic Nail System. Secondly, the humeral nail geometry was rather straight than the femoral nail resulting in the more lateral entry point for humeral nail insertion at the lateral to the tip of the greater trochanter, and so avoiding the iatrogenic vascular injury on piriformis fossa.

Then medical management with Zolendronic acid given as 0.05 mg/kg/dose every 6 months Calcium 1000 mg once a day for 2 months and Vitamin D 600 IU daily for one month. Later reviewed with blood parameters to add medication.

Hip thigh orthosis also applied long-leg braces (hip-knee-

Figure 4: X-ray after 2 months & after 6 months

Figure 5: X-ray after one year & scar mark

TYPE	TOTAL CASES	TOTAL NUMBER OF CASES UNION	TOTAL NUMBER OF CASES NONUNION	NONUNION PERCENTAGE
TYPE 1	22	19(48.7)	3(30)	13.60%
TYPE 2	0	0 (0)	0 (0)	0%
TYPE 3	13	12(30.7)	1(10)	7.70%
TYPE 4	13	7(18)	6(60)	46%
TYPE 5	0	0(0)	0 (0)	0%

Table 2: Incidence of Nonunion in different types of OI

ankle-foot orthoses [HKAFO] or RGO Reciprocating Gait Orthosis. The RGO provides support and mobility to the hip, knee, ankle, and foot. It improves body alignment and posture, increases bone and muscle strength, and enhances independence and self-esteem [36].

Physiotherapy helped to prevent disuse atrophy of muscle strengthen muscles and disuse loss of bone mass strengthen the bone. Weight-bearing started after 3 months and on serial X-ray, the union was visible with correction of the deformity. The patient had a good functional recovery.

OI is a heritable disorder of collagen synthesis that commonly presents as bone fragility with multiple long bone fractures and

deformities that require multidisciplinary treatment surgical management for fracture fixation or reconstruction with medical treatment for increased density of bone.

The implant selection is very problematic given the age of the patient's deformity fracture, the density of bone. The various implant used for fixation of OI intramedullary Rush Pin, TENS Tensile Elastic Nail System, Femoral nail Recently Telescoping nail–Bailey Dubow, Sheffield, Fassier Duval, cork-tipped telescoping nail

and Extramedullary device–plates external fixator with various advantage and downside. The load sharing implant intramedullary device is better advantages of early mobilization of hip and knee, efficient load transfer, optimal mechanical stability, minimization of stress concentration, preservation of soft tissues, fracture hematoma, and periosteal blood supply [37,38].

The usefulness of the Humerus nail has many advantages compared to the Rush pin, TENS Tensile Elastic Nail System, Conventional femoral nail, Telescoping nail. Rush Pin, TENS Tensile Elastic Nail System has poor stability as seen during this case implant failure with non-union was seen. The conventional Femoral nail mismatch with the narrow diameter of OI patient femur and Telescoping Rod high cost with less availability with the complication of migration, epiphyseal injury.

The Humerus nail Advantages

1. Humerus nail is straight so entry is lateral from trans trochanteric because the diameter of the nail is less so injury to the epiphysis and vessel MCA is minimized.
2. They provide better biomechanical stability rotation of limbs in multiple osteotomies.
3. In OI patient is short stature with narrow diameter Humerus nail is more suitable in view of the nail is having a shorter length and small diameter.

The Humerus nail disadvantages are also there.

1. Distal locking of distal femur needs a longer screw
2. This nail has a 9–10-degree cephalon medullary angle better for proximal femur fracture [39].

We fixed non-union femur with deformity with Implant failure by using Humerus nail in OI III patient. A study published where they reviewed 216 adults OI patients on the incidence of femur fractures and non-unions, presenting a total of 49 femur fractures (22.7%) and 10 non-unions (20.4%)

Type 4 has the most non-union rate during this study Agarwal and Joseph and Gamble et al. found a 15–20% prevalence of fracture non-union in a very heterogeneous group of OI children over a 10–14-year period [40,41,42].

So, our case is rare as per the non-union percentage rate in OI type III.

Regarding osteotomy, the fracture at midshaft which was non-union oblique in the pattern was again osteotomized to refresh and use as rotational osteotomy and therefore the transverse osteotomy at proximal femur was used as translational osteotomy correct bowing malalignment. The fixation of the femur after osteotomy was with Humerus nail correcting the deformity and healing the non-union femur which is unusual because of rare presentation.

Medical management, Physiotherapy, Orthotic support helped the fast recovery of patients with better functional outcomes.

Conclusion

In Adolescent OI patients with a rare percentage of nonunion with implant failure of femur and deformity can be fixed with Humerus nail. It gives stable fixation with deformity correction by both rotational osteotomy oblique non-union site Osteotomized refreshed and translational osteotomy transverse at subtrochanteric level with the conversion of non-union to union with a better result.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his/her consent for his/her images and other clinical information to be reported in the Journal. The patient understands that his/her name and initials will not be published, and due efforts will be made to conceal his/her identity, but anonymity cannot be guaranteed.

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