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Original Article

CLINICAL AND RADIOLOGICAL EVALUATION OF MONOPLANAR EXTERNAL FIXATOR IN ACUTE CORRECTION OF MULTIPLANAR KNEE DEFORMITIES IN ADOLESCENTS; A PROSPECTIVE COHORT STUDY

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Abstract

Background: *External fixators constitute a crucial component of treatment strategies for complex deformities in the lower limbs. This work aimed to assess the clinical and radiological correction of multiplanar deformities around the knee in adolescents.* ***Methods:*** *This prospective cohort study was carried out on 30 patients with more than one plane deformity, genu valgus having a tibiofemoral angle of more than 15 degrees or a metaphyseal-diaphyseal angle of more than 11 degrees, and full extension and more than 100 degrees of flexion. Follow-up weight-bearing long film X-rays were done two weeks, one month, three months, and four months postoperatively.* ***Results:*** *Medial proximal tibial angle (MPTA), lateral distal femur angle (LDFA), and range of motion (ROM) of the knee were significantly higher at 2 weeks, 1m, 3m, and 6m than preoperative (P <0.001). The pain score after removal of external fixation was mild in 63.3% of patients, moderate in 30% of the patients, and severe in 6.7% of the patients. Regarding complications, pin tract infection occurred in 33.3% of the patients, and superficial infection at the osteotomy site occurred in 10% of the patients.* ***Conclusions:*** *Using a monoplanar external fixator for the acute correction of multiplanar knee deformities improves the knee's structural alignment by correcting the MPTA and LDFA leading to better load distribution across the knee joint, reduced pain, and enhanced ROM.*

Keywords: *Correction, Monoplanar External Fixator, Multiplanar Knee Deformities, Radiological.*

1. Introduction

Variations in the normal growth pattern often led to angular deformities around the knee in children. When these deformities are not corrected, they can alter the biomechanics of the knee, impacting the distribution of stress across the weight-bearing surface of the joint [1]. Deformations in the long bones of the lower limbs can arise due to multiple factors such as the aftermath of injuries, metabolic abnormalities, bone growth disorders, infections, and inherent deficiencies of the limb. The long-term consequences of misalignment in the lower extremities remain uncertain [2]. Lower extremity angular deformity arises in any of the three planes (coronal, sagittal, and transverse). These deformities can lead to gait abnormalities, pain, or the development of future arthritis and disability. Correction of deformity around the knee depends on the position of the center of rotation of angulation and the degree of deformity [3]. Valgus and varus deformities in the knee can lead to various complications such as discomfort, instability of the knee, damage to ligaments, and degradation of cartilage. Furthermore, these types of knee deformities can adversely affect a person's ability to walk [4]. Orthopedic surgeons often encounter complex challenges when treating lower limb deformities characterized by multiple, varied origins and presenting in several directions [5]. Traditionally, internal fixation methods, which involve performing open osteotomies and immediate correction, are employed for deformity correction [6]. However, these tec-

hniques may be less effective for complex deformities, especially when accompanied by discrepancies in leg length [7]. Recently, external fixators have become increasingly favored in orthopedics, particularly for managing complicated deformities and assisting in bone elongation processes [8]. The use of a monolateral external fixator combined with osteotomy has been found to be more effective, offering simplicity, precise correction, fewer complications, the capability to adjust both valgus and varus deformities, and enabling earlier patient mobility [9]. This work aimed to assess the clinical and radiological correction of multiplanar deformities around the knee in adolescents.

2. Patients and Methods

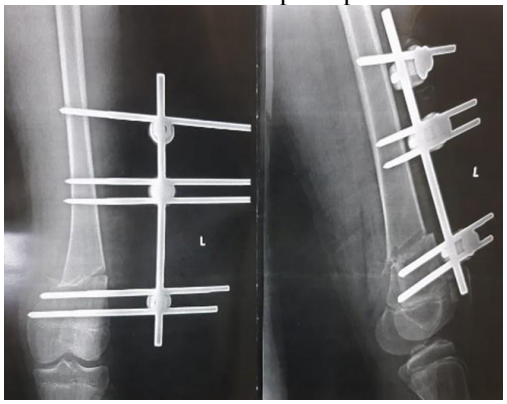
This prospective study was carried out on 30 patients aged from 10 - 16 years old at the orthopedic department of a tertiary hospital in the period from March 2023 to February 2024. The study included cases from both sexes, with more than one plane deformity, genu valgus having tibio-femoral angle of more than 15 degrees or metaphyseal-diaphyseal angle of more than 11 degrees, and full extension and more than 100 degrees of flexion. We excluded patients with genu recurvatum associated with severe generalized hyperlaxity, and knee flexion deformity.

2.1. *Ethical consideration*

The research protocol was reviewed and permitted by the institutional research and ethics committee (Approval code: Soh-Med-23-11-12PD). After participants and their guardians were adequately briefed on the study's goals, a written informed consent was obtained. Participation was entirely voluntary. According to the Declaration of Helsinki, all steps of data collecting, entry, and analysis were conducted in a highly confidential and private manner. All patients were subjected to clinical assessment of the deformity by Staheli rotational profile assessment, valgus malalignment usually associated with external torsion of the distal femur versus Varus malalignment usually associated with internal torsion of the proximal tibia, and radiological assessment using planning X-ray of the whole lower limbs. Monoplanar external fixator technique: small skin incision done over middle third of fibula then fibular osteotomy or fibulectomy. Two Schanz screws were inserted in the metaphyseal part just distal to the physeal plate parallel to the knee joint then another two Schanz screws were inserted in the tibial diaphysis parallel to the ankle joint with 4 cm apart from both proximal and distal two. Two Schanz screws were inserted in the metaphyseal part just proximal to the physeal plate parallel to the knee joint then another two Schanz screws were inserted in femoral diaphysis perpendicular to femoral mechanical axis with 4 cm apart from both proximal and distal two. Drilling was done using 3.2 drill bit prepared for osteotomy. Role number 2 is used in osteotomy. A better osteotomy technique is oblique to ensure a large bony contact surface during reduction, and an intraoperative cable technique is used to restore the alignment of the lower limb. Clambs and rods were introduced to maintain the frame of the external fixator. Also, Schanze screws could be inserted in two different planes between proximal and distal Schanze screws to correct concomitant rotational malalignment. The number of Schanz, clamps, and rods may increase to increase the stability of the external fixator, fig. (1).

Figure (1) Alignment and osteotomy intraoperative

Post-operative evaluation: clinical assessment of the wound, Schanz screws pin tract cleaning, and deformity correction done. All patients were allowed to immediately do weight-bearing exercises using crutches with both passive and active knee exercises. Daily cleaning of pins with isotonic saline solution to avoid pin tract infection. Follow-up weight-bearing long film X-rays were done in 2 weeks, 1 month, 3 months, and 4 months postoperative, fig. (2). Removal of external fixator after complete bony consolidation 3 to 4 months postoperative.



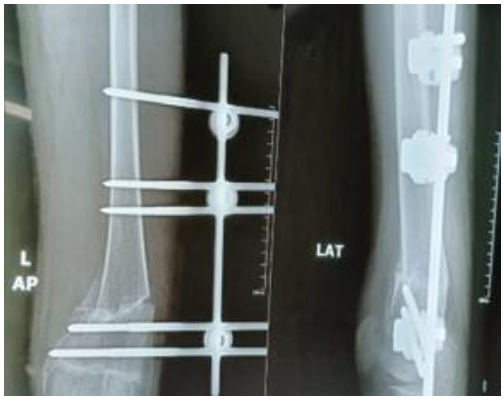


Figure (2) Postoperative follow up X rays

2.2. Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Chicago, IL, USA). Quantitative variables were presented as mean and standard deviation (SD) and compared between the measurements utilizing repeated measure ANOVA. Qualitative variables were presented as frequency and percentage (%). A two tailed P value < 0.05 was considered statistically sig-nificant.

3. Results

This study included 30 patients from 10 - 16 years old with a mean age of 11.7 (±1.55) years. Males represented 17 (56.67%) patients, and females were 13 (43.33%) patients. The type of deformity was right genu valgus in 2 (6.67%) patients, left genu valgus in 8 (26.67%) patients, right genu varum in 7 (23.33%) patients and left genu varum in 13 (43.33%) patients. The mean value (± SD) of union duration was 2.2 (±0.49) months, tab. (1). MPTA, ROM of knee, and LDFA were significantly higher at 2 weeks, 1m, 3m, and 6m than preoperative (P <0.001), tab. (2) & fig. (3). Pain score after removal of the external fixator was mild in 19 (63.33%) patients, moderate in 9 (30%) patients, and severe in 2 (6.67%) patients. Regarding complications, pin tract infection occurred in 10 (33.33%) patients, and superficial infection at the osteotomy site occurred in 3 (10%) patients, tab. (3).

Table (1) Demographic data and duration of union of the studied patients

		Mean ± SD (n=30)
Age (years)		11.7 ± 1.55
Duration of union (months)		2.2 ± 0.49
		Count (%) (n=30)
Sex	▪ ***Male***	17 (56.67%)
	Female	13 (43.33%)
Type of deformity	▪ ***Right genu valgus***	2 (6.67%)
	▪ ***Left genu valgus***	8 (26.67%)
	▪ ***Right genu varum***	7 (23.33%)
	▪ ***Left genu varum***	13 (43.33%)

Table (2) MPTA, LDFA and ROM of knee of the studied patients

	Preoperative	**2 weeks**	**1 month**	**3 months**	**4 months**
MPTA (mean ± SD)	90.9 ± 2.26	92.5 ± 2.24	94 ± 2.13	94.6 ± 2.17	94.9 ± 2.19
P-value		**<0.001***	**<0.001***	**<0.001***	**<0.001***
LDFA (mean ± SD)	74.7 ± 5.9	76.2 ± 6	77.1 ± 5.87	80.4 ± 6.28	81.2 ± 6.26
P-value		**<0.001***	**<0.001***	**<0.001***	**<0.001***
ROM of knee (mean ± SD)	100.8 ± 16.56	106.5 ± 16.36	113 ± 16.69	117.8 ± 16.54	118 ± 15.06
P-value		**<0.001***	**<0.001***	**<0.001***	**<0.001***

***Significant as P value≤0.05.** **LDFA:** Lateral distal femur angle. **MPTA:** Medial proximal tibial angle. **ROM:** Range of motion.*

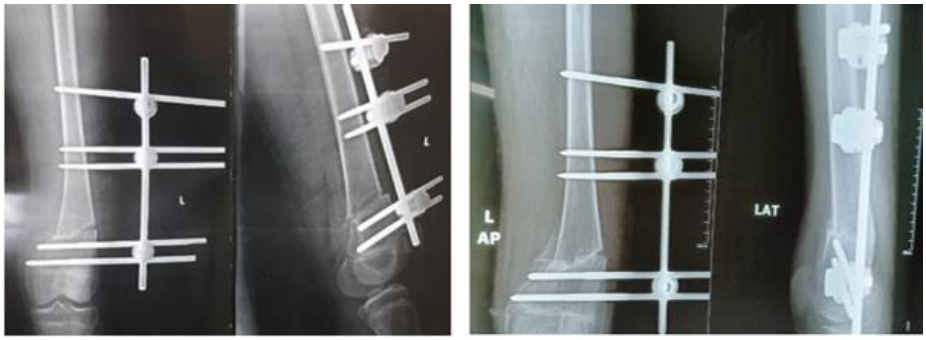


Figure (3) Clinical and Radiographic follow up

Table (3) Pain score and complications of the studied patients

		Count (%) (n=30)
Pain score after removal of external fixator	▪ ***Mild***	19 (63.33%)
	▪ ***Moderate***	9 (30%)
	▪ ***Severe***	2 (6.67%)
Complications	▪ ***Pin tract infection***	10 (33.33%)
	▪ ***Superficial infection at osteotomy site***	3 (10%)

4. Discussion

Knee biomechanics are altered when angular deformities occur, as the weight-bearing surface of the knee joint experiences an unbalanced distribution of stress. Frontal plane abnormalities of the tibia or femur resulted in malorientation of the joints above and below the level of deformity and mechanical axis deviation of the lower limb [10]. A Monoplanar external fixator is used for the correction of bone deformities or fractures. It consists of external metal frames attached to the bone by pins or wires, which are then adjusted to gradually correct the alignment of the bone over time. In multiplanar deformities, such as varus or valgus deformities, external fixators can be used as part of the treatment plan [11]. A Monoplanar external fixator may be employed to provide stability and facilitate gradual correction of the deformity to achieve acute correction [12]. The use of external fixators in knee deformity correction allows for precise adjustment of the alignment, which is essential for achieving optimal functional outcomes. However, the process typically involves a gradual correction over time to minimize complications such as neurovascular injury or soft tissue damage [13]. In our study, MPTA, LDFA, and knee ROM were significantly higher at 2 weeks, 1m, 3m, and 6m than preoperatively. The pain score after removing the external fixation fix was mild in 63.33% of the patients, moderate in 30% of the patients, and severe in 6.67% of the patients. In agreement with our results, Jiao et al. [14] who noticed that the MPTA, and LDTA were improved 12 months after multi-planar tibial deformity correction surgery. Also, Fadel and Taha [15] found that MPTA and LDFA of the knee were significantly higher post-operatively than preoperatively. Additionally, Ghasemi et al. [16] demonstrated that a significant improvement of MPTA was observed after genu varum correction with an external fixator. Moreover, Lim et al. [17] demonstrated that MPTA improved significantly after surgical correction of proximal tibia deformity in small children using a mono-lateral external fixator. Also, Özkul et al. [18] showed that there was a statistically significant increase in MPTA from 76° to 89° after bilateral correction of genu varum with a smart frame. Additionally, Pandya et al. [19] illustrated that there was a statistically significant increase in MPTA after surgical correction of Blount disease using multiple axial corrections. Regarding complications in this study, pin tract infection occurred in 33.33% of the patients, and superficial infection at the osteotomy site occurred in 10% of the patients. Hui et al. [20] illustrated that 25% of the patients had superficial infections. Fadel and Taha [15] found that there were 6.66% had pin tract infections. Our results came in line with Pereira et al. who reported that the pain score after fixator removal was lower than the pain immediately after the procedure [21]. Also, Myers et al. noticed that there were 10% of the patients had wound infection, and 26.6%

of the patients had pin tract infection [22]. While external fixators are effective in promoting bone healing and stability, they also carry a risk of pin-tract infections, particularly when compared to other types of external fixators, but these pin-tract infections are very responsive to oral antibiotics [23]. The direct penetration of pins or wires to fix the device to the bone increases the risk of introducing bacteria from the skin surface into the deeper tissues, leading to infection [24]. Also, monoplanar external fixators stabilize bone fragments in a single plane, so they have fewer fixation points that concentrate the pressure on a smaller area leading to tissue irritation and compromised blood flow, making it easier for bacteria to colonize and cause infection [25]. Monoplanar external fixators also provide limited soft tissue coverage around the pin sites that may offer more extensive coverage with rings or additional structures. Insufficient soft tissue coverage increases the risk of contamination of pin sites from the external environment [26]. Additionally, monoplanar external fixators may lack dynamic compression capabilities, which can lead to micromotion at the pin-bone interface. This micromotion can create a pathway for bacteria to enter the pin tract, increasing the risk of infection [27]. Limitations in this study involved the relatively small sample size, the study's being in a single center, and the relatively short follow-up period of patients. To mitigate the risk of pin-tract infections, proper surgical technique, perioperative antibiotic prophylaxis, meticulous pin site care, and close monitoring for signs of infection are recommended.

5. Conclusions

Using a monoplanar external fixator for the acute correction of multiplanar knee deformities directly improves the knee's structural alignment by correcting the MPTA and LDFA. This realignment leads to better load distribution across the knee joint, reduced pain, and enhanced ROM due to the removal of mechanical constraints and the restoration of more normal knee anatomy and function.

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