Lower limb deformity correction using Ortho-SUV frame in skeletally mature patients

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Background
Gradual correction of lower limb deformity using the Ilizarov apparatus is an established method. The Ortho-SUV frame is a computer-assisted system that simultaneously allows accurate and timely correction of various deformities.
Patients and methods
This prospective study included 13 patients with various lower limb deformities (femur and tibia) treated with an Ortho-SUV frame in one center between October 2020 and December 2023.
Results
The correction time ranged from 3 to 49 days. Correction accuracy was full in 12 (92.31%) patients and residual 10 degrees of plantar flexion in one (7.69%) patient. The number of schedules for correction was one in four (30.77%) patients, two in eight (61.54%) patients, and three in one (7.69%) patients. The union time ranged from 79 to 285 days, with a mean of 154.3 (±60.9). The time in frame ranged from 81 to 362 with a mean of 204 (±86.37). The follow-up duration ranged from 5.8 to 38.17 months, with a mean of 24.59 (±11.05).
Conclusion
Lower limb deformity correction using the Ortho-SUV resulted in the accurate correction of simultaneous deformities.

Keywords:
deformity correction, external fixation, hexapod external fixator, lower limb deformity, Ortho-SUV

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Introduction

Two methods are mainly used for managing lower limb deformity: osteotomy with internal fixation or osteotomy with external fixation [1]. Internal fixation provides an acute means of correction, but accurate correction must be obtained at the time of surgery without the possibility of postoperatively modification [2]. On the other hand, external fixation provides a gradual means of correction with the ability to modify initial results postoperatively [3].

The Ilizarov apparatus is considered a standard method for correcting long bone deformities. One disadvantage of the Ilizarov device is that it is time-consuming and requires a technically complicated construction process with highly skilled surgeons, especially in bones with multiple deformities [3].

The Ilizarov method has evolved into a new generation of hexapod fixators, which provides several benefits, such as using computer software to reach the optimal frame assembly and process the required number of strut adjustments to achieve the planned correction [4]. The major advantage is having simultaneous correction in all planes and lengthening. The Taylor spatial frame is the earliest successful commercially available hexapod, followed by several types from different manufacturers [5].

The Ortho-SUV frame is a hexapod circular external fixation device that uses computer assistance for three-dimensional deformity correction. Consisting of six struts that can be attached to standard Ilizarov rings [6]. Its capability of correcting the deformity in six axes in all planes is achieved with computer software, which improves the correction accuracy and reduces correction time compared to other external fixators [7]. The Ortho-SUV's computer software is simple to use, as the radiographs are added directly to the software. The software's tools allow for drawing bone dimensions. The program can then predict the course of deformity correction, allowing the surgeon to control the correction process to achieve the desired results [4].

Many studies have investigated the accuracy of the Ortho-SUV frame [6,8]. It was concluded that

Ortho-SUV frame is more than 90% accurate in correcting femoral/tibial deformities compared to the traditional Ilizarov frame. Also, the correction time using the Ortho-SUV frame proved to be shorter than Ilizarov [9]. We have investigated a consecutive group of patients suffering from various deformities treated with Ortho-SUV in our center.

Patients and methods

This prospective study was carried out at the Orthopedic Surgery Department at Benha University from October 2020 to December 2023. It included 13 patients with femoral, tibial, and ankle deformities, ages ranging between 18 and 60. Lower limb deformities were due to either posttraumatic nonunited fractures, infection, or developmental conditions. All patients were operated on by a single surgeon (A.A.E.). We excluded patients with chronic severe illness, malignancy, or mental health issues that preclude the use of an external fixator. The study was approved by the institutional ethics committee at Benha University. Informed consent has been obtained from all the patients in this study, and the study has been accepted and approved by the Research Ethics Committee of Benha Faculty of Medicine, Benha University (REC-FOMBU MoHP No:0018122017/Certificate No:1017) under number MS 3-5-2020.

The age ranged from 18 to 65 years with a mean of 39.64 (±15.88) years in patients with femur and tibia deformities and ranged from 17 to 34 years with a mean of 25.5 (±12.02) years in patients with ankle deformities. There were 10 (90.91%) males and one (9.09%) female in patients with femur and tibia deformities and two (100%) males in patients with ankle deformities.

Three patients had femoral deformity, one patient had shaft deformity, and two patients had distal femoral deformity; tibial deformity was present in eight; four patients had tibial shaft deformities, two patients with proximal and two patients with distal tibial deformities. Ankle deformity was present in two patients (Table 1).

According to the etiology, 54% had malreduced neglected fractures, 23% had genu varum, 15% (two patients) had fixed ankle equines, and one (8%) patient had deformity at the docking site following bone transport.

Methods

The preoperative evaluation was done for all patients by careful history taking and accurate general and clinical examination, which included evaluation of the local neurovascular status of the affected limb and assessment of soft tissues around the planned osteotomy site. Also, radiological evaluation with standing long leg film and separate regional radiographs of the bone segment, then deformity analysis was done to measure anatomic lateral distal femoral angle (aLDFA), medial proximal tibial angle (MPTA), lateral distal tibial angle, leg length discrepancy in the coronal view, the posterior distal femoral angle, and posterior proximal tibial angle (PPTA) in the sagittal view.

Operative technique

The patient was supine. General or spinal anesthesia was administered, followed by the application of the frame and the struts. If needed, tibial, fibular, or femoral osteotomy was performed according to the plan, followed by obtaining the length of the struts and the distances required by the software.

Postoperative analysis

Obtaining an radiograph as per manufacturer instructions, feeding the data to the software, and then obtaining the schedule of the daily adjustments. The Ortho-SUV system offers standard, short, and extra-long struts, and in all the cases, standard struts were used. However, the length-changing unit needed to be reset during the correction schedule without the need to change the strut itself using the reverse mechanism of the strut.

After finishing the schedule, a new radiograph was done to determine the need for residual correction. Patients were assessed regularly till the end of the adjustments. Afterward, struts were changed by standard threaded rods until the full union was achieved. This was followed by measurement of the corrected angles accordingly: aLDFA, MPTA, lateral distal tibial angle, leg length discrepancy in the coronal view, the posterior distal femoral angle and PPTA in the sagittal view. Also, analysis of the quality and time of the correction, number of schedules, and complications during or after correction.

Statistical analysis

Statistical analysis was done using SPSS, v26 (IBM Inc., Chicago, Illinois, USA). Quantitative variables were presented as mean and SD. A two-tailed P value less than 0.05 was considered statistically significant.

Results

MPTA was significantly higher in postoperative than preoperative (P=0.031). PPTA was slightly higher postoperatively (P=0.042). aLDFA and MAD were significantly lower postoperatively than preoperatively (P<0.001 and P=0.021, respectively) (Table 2).

Table 1 Descriptive data of the deformities in the study group

Patient no.	Anatomic region	Sex	Age	Cause of deformity	Angular deformity	Oblique plane deformity	Rotational deformity	Translation
1	Femur	Male	38	Delayed fracture management (posttraumatic)	7 varus and 24 recurvatum	25		50% in anteroposterior view to the medial side
2	Femur	Male	19	Delayed fracture management (posttraumatic)	5 valgus and 15 recurvatum			100% in anteroposterior view 2 cm bone overriding
3	Femur	Male	65	Delayed fracture management (posttraumatic)	15 varus			25% in lateral view
4	Tibia	Male	18	Genu varum (developmental)	19 varus and 15 procurvatum	24	5 internal rotation	
5	Tibia	Male	45	Genu varum (developmental)	13 varus and 6 procuvatum	14	15 internal rotation	
6	Tibia	Male	21	Genu varum (developmental)	19 varus and 17 procuvatum	25	15 internal rotation	
7	Tibia	Male	35	Docking site infection (posttraumatic)	10 procurvatum and 10 varus	14		
8	Tibia	Male	37	Delayed fracture management (posttraumatic)	5 valgus and 10 recurvatum	12		
9	Tibia	Female	55	Delayed fracture management (posttraumatic)	6 valgus and 20 recurvatum	21		
10	Tibia	Male	57	Delayed fracture management (posttraumatic)	12 procurvatum	12		10% in anteroposterior view to the lateral side
11	Tibia	Male	46	Delayed fracture management (posttraumatic)	6 varus	6		100% in the anteroposterior view to the medial side and 25% in the lateral view to the posterior
12	Ankle	Male	34	Equinus (posttraumatic)	Plantar flexion (equinus) 30			
13	Ankle	Male	17	Equinus (post-infection)	Plantar flexion (equinus) 50			

Table 2 Radiological evaluation of the studied patients

	Preoperative	Postoperative	
MPTA (degrees)			
Mean±SD	68.3±11.5	90±1	0.031*
Range	57–80	89-91	
PPTA (degrees)			
Mean±SD	64±0	79±0	0.042*
Range	64–64	79-79	
aLDFA (degrees)			
Mean±SD	91.8±2.22	80.8±0.96	<0.001*
Range	90–95	80-82	
MAD (mm)			
Mean±SD	83.7±36.64	6±1.73	0.021*
Range	49-122	5-8	

aLDFA, anatomic lateral distal femoral angle; MPTA, medial proximal tibial angle; PPTA, posterior proximal tibial angle.
*statistically significant (<0.05)

The correction time ranged from 3 to 49 days, with a mean of 27.69 (±13.36) days. Correction accuracy was full in 12 (92.31%) patients and residual 10 degrees of plantar flexion in one (7.69%) patient. The number of schedules for correction was one in four (30.77%) patients, two in eight (61.54%) patients, and three in one (7.69%) patients. The union time ranged from 79 to 285 days, with a mean of 154.3 (±60.9). The time in frame ranged from 81 to 362 with a mean of 204 (±86.37). The follow-up duration of the studied patients ranged from 5.8 to 38.17 months, with a mean of 24.59 (±11.05) months (Table 3, Figs 1–3).

Discussion

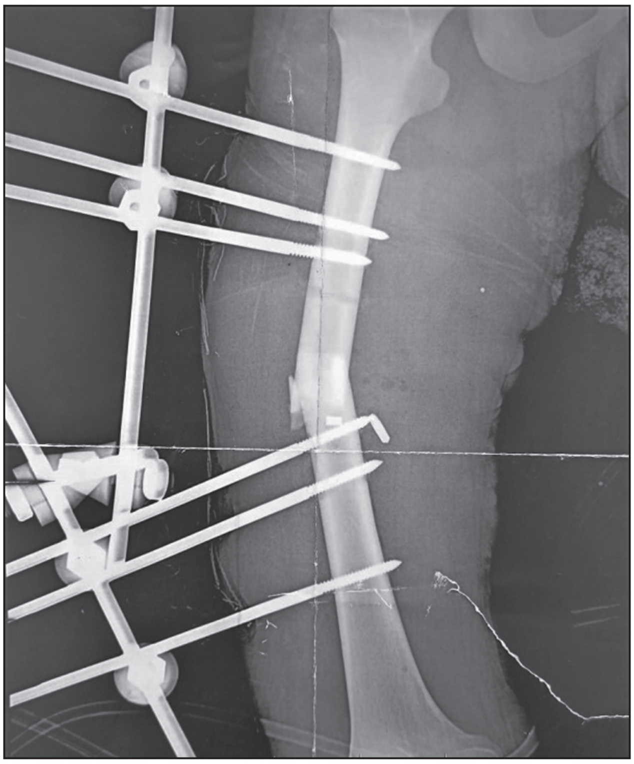
Lower limb deformities lead to impairment of the patient's function due to alteration of force transmission across adjacent joints [7]. The etiology of lower limb deformity may be congenital, metabolic, traumatic, or tumors it still represents a difficult challenge for the treating surgeon depending on several factors such as the nature of the deformity, availability of the hardware used, and the experience and skill of the surgeon himself [7].

Using the Ilizarov apparatus external fixator requires multiple modifications of the frame to gradually correct angulation, length, translation, and rotation in different stages. This leads to a prolonged correction process and repeated imaging throughout the treatment process [10].

Table 3 Correction time, correction accuracy, number of schedules for correction, union time, time in the frame, and follow-up duration of the studied patients

	N=13
Correction time (days)	
Mean±SD	27.7±13.36
Range	3–49
Correction accuracy [*n* (%)]	
Full	12 (92.31)
Residual 10 degrees of plantar flexion	1 (7.69)
Number of schedules for correction [*n* (%)]	
One	4 (30.77)
Two	8 (61.54)
Three	1 (7.69)
Union time (days)	
Mean±SD	154.3±60.9
Range	79–285
Time in frame	
Mean±SD	204±86.37
Range	81–362
Follow-up duration (months)	
Mean±SD	24.6±11.05
Range	5.8–38.17

Figure 1



Preoperative radiograph showing the femur fixed by an external fixator of a 19–year-old male patient with a 2–week-old open femoral shaft fracture, which was fixed initially by a poly axial external fixator. The angular deformity was 5 degrees of valgus deformity and 15 degrees of recurvatum. Translation deformity was 100% in anteroposterior view with 2 cm bone overriding leading to shortening.

For several decades, the Ilizarov system was used to correct deformities. The disadvantages of the traditional Ilizarov frame were overcome by the introduction of the newer computer-assisted hexapod systems that can perform correction for complex deformities, such as the Ortho-SUV frame, Taylor Spatial Frame, Orthofix TL Hex, etc. [11].

The Ortho-SUV frame is flexible, as it utilizes actual radiographs in planning the correction process using computer software. The struts can be used with any external fixator ring [6,12].

In our study, we review the use of the Ortho-SUV frame in correcting lower limb deformities, highlighting its advantage over the traditional Ilizarov technique. The process of deformity correction addresses all the components of the deformity simultaneously with high accuracy in correcting translation, angulation, and rotational deformity.

Our study included 13 patients with lower limb deformity, with most having tibial deformity (eight patients). Solomin and colleagues compared the use of the Ortho-SUV system with the Ilizarov apparatus in 127 cases with femur deformity and concluded that using the Ortho-SUV system facilitates deformity correction and reduces the time required for the correction process by 2.3 folds in complex deformity and 1.6 folds in middle shaft deformity. Accuracy was significantly higher than correction with a traditional Ilizarov ring fixator [6].

In our study, full deformity correction was achieved in 92.31% of the study group, with only one patient with residual 10 degrees of plantar flexion deformity.

Another study by Solomin and colleagues on femoral deformity included 47 patients who underwent correction using the Ortho-SUV system and showed that the Ortho-SUV frame decreases the time to obtain good results compared to the traditional Ilizarov system [6]. In this study, we utilized Ortho-SUV frame to gradually reduce neglected mal-positioned femoral fractures in three patients with good results.

Javier and colleagues reported a success rate of 87% using the Ortho-SUV frame. However, three cases underwent soft tissue interposition removal. Patients with simple deformities needed a shorter time to achieve correction, with an average of 34.4 days, while patients with moderate and complex deformities required twice that time [8]. In our study, we corrected the deformity in a mean of 27.69 days, with a mean schedule for correction needed of 1.76.

Takata *et al.* [13] published a study in 2013 that included nine patients with forefoot and hindfoot

Figure 2

Postoperative radiological and clinical photos showing the Ortho-SUV struts assembled with standard Ilizarov rings, which were applied 4 weeks following the initial injury to correct the femoral deformity gradually.

Figure 3

Anteroposterior and lateral views radiographs after frame removal and fracture consolidation. The patient needed two correction schedules through the correction process. First schedule was to apply distraction, and the second schedule corrected angulation. Correction took 29 days, and the full union was obtained uneventfully after 175 days.

deformities treated with the Ortho-SUV frame and showed good results, with all deformities corrected as planned.

While addressing tibial deformity, Ariyawatkul *et al.* [9] conducted a study in 2016, including 13 patients with complex tibial deformity. Seven patients were managed using the Ortho-SUV frame system, which reduced the lengthening index in comparison to the traditional Ilizarov system. We used Ortho-SUV frame in three proximal tibial multiplanar deformity corrections, and we applied the planned correction of tibial deformity at a mean of 23.37 days with a mean number of schedules for correction of 1.62.

In 2022, Low and colleagues achieved radiological union at the end of the study, with 10 patients scoring excellent and three patients scoring well. While for functional outcome, nine patients scored excellent, and four patients scored well according to the ASAMI criteria [14]. In our study, we corrected three femoral deformities in three patients with no complications.

The Ortho-SUV device has shown to be versatile in the mood of application as Singh and colleagues published a study in 2021 and succeeded in correcting the deformity in all patients except two patients in which failure of correction was due to abutment in the medial side by protruding struts requiring early hardware removal in one patient with proximal femur deformity and strut length exhaustion in the other patient [15].

In our study, we encountered one case of mechanical abutment of the struts against the femoral arch that needed re-configuration, so we started a new schedule for correction. However, we did it in the clinic without the need for further operative procedures.

Accurate preoperative planning is essential to obtain an intraoperative stable construction to avoid excessive movement of the pins relative to the bone, which increases the possibility of pin tract infection [16]. The treating surgeon should be prepared with a protocol to follow through the process to avoid injury to the surrounding skin, neurovascular structures, and bone and lower the risk of postoperative infection.

Limitations

The limitations of this study are the small number of patients due to the system's recent introduction to the Egyptian market and the heterogeneous types of deformities and different anatomical areas included.

Conclusion

The Ortho-SUV frame is an effective, convenient, and accurate tool for correcting lower limb deformities. It allows simultaneous correction of multiple angular, rotational, translational, and longitudinal deformities in different anatomical regions with other etiologies. It proved versatile in the application mood yet more accurate than the standard Ilizarov system. We recommend further studies as the device is relatively new to the Egyptian market.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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