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RESEARCH ARTICLE

Correcting Angular Limb Deformities of Radius-Ulna and Tibia in Nine Dogs Using Computer-Assisted Spider Frame System

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ABSTRACT

In this study, angular deformities in 9 dogs, including 8 antebrachium and 1 tibia, were corrected using hexapod external fixators with the help of the computer-aided Spider Frame system.Preoperative planning included measurement of craniocaudal and mediolateral angular deformities, rotational deformity, length deficit, as well as determination of the source of the deformity and assembly of the frame.Joint lines and osteotomy/ostectomy lines were determined according to CORA points determined during preoperative measurements. Proximal and distal rings were placed. After the installation of the spider, radial/ tibial osteotomy/ostectomy was performed at the CORA point of the radius/tibia. After the operation, craniocaudal and mediolateral radiographs were taken in all cases. Ring dimensions, angular deformity values (including angulation, translation and rotation) and the degree of shortening were evaluated by radiographs. These data were entered into the web-based Spider software to generate correction prescriptions, after which the length and deformity correction process started on postoperative days 3-5. Functional results were excellent in seven cases and good in the other two cases. Long-term cosmesis was good to excellent in all cases.In conclusion, Spider Frame is a new generation external fixator system with many technical advantages and we recommend its use in appropriate cases.

Keywords: Dog, Angular deformity, Corrective osteotomy, Computer-assisted spider frame system

INTRODUCTION

Correction of limb deformities using the Ilizarov circular external fixator has been employed in both humans and dogs for a considerable time [1-4]. However, correcting complex deformities by means of this device poses some serious challenges, one of which is the need to modify the system to prevent residual deformity. If the deformity is to be corrected gradually, then sequential angulation, lengthening, rotation, and translation treatments must be performed [5]. When treating complex deformities, the Ilizarov circular external fixator needs to be modified and the correction period be prolonged. This explains the reason why computer-assisted use of hexapod external fixators have been in fashion for the past 15 years [6-8]. Such devices have been employed to treat both open and closed fractures, non-union and malunion cases, as well as limb deformities [9-11].

The Spider Frame is a hexapod fixator that consists of two rings connected to each other by six telescopic struts at special universal joints and is attached to the bone using half pins and/or tensioned wires. Each strut can be independently lengthened or shortened, enabling manipulation of the attached bone in six axes (anterior/posterior, varus/valgus, lengthen/shorten) through the adjustable struts [12-15].

In this study, we attempted to correct angular deformities in dogs using hexapod external fixators with the help of the computer-assisted Spider Frame system. Therefore, the study was aimed at evaluating the effectiveness of the Spider Frame and Spider Frame Correction Software in treating shortness and different types of deformities in nine dogs

MATERIAL AND METHODS

Ethical Approval

Ethics committee approval was not obtained because Spider frame was applied as a clinical study in dogs with angular deformity. After the necessary information was

Table 1. *Breef summary of the cases and change in deformity in parameters*

Case	Signalement	Deformity Description before Operation
Case 1	Kangal, 35 kg 10 m, ♀	Carpal valgus, CrCd 25°Valgus ML 30°Procurvatum, External Rotation 20°
Case 2	Alabay ,50kg 11 m, ♂	carpal valgus, CrCd 20°Valgus ML 45° Procurvatum, External Rotation 30°
Case 3	Husky, 32 kg 16 m, ♂	Carpal valgus CrCd 30°Valgus ML 40° Procurvatum, External Rotation 40°
Case 4	Kangal, 48 kg 12 m, ♂	carpal valgus CrCd 18° ML 60°, External Rotation 70°
Case 5	Kangal, 43 kg 8 m, ♀	carpal valgus, CrCd 28° ML 50°, External Rotation 10°
Case 6	Kangal, 55 kg 10 m, ♂	carpal valgus, CrCd 35° ML 47°, External Rotation 30°
Case 7	Kangal, 65 kg 8.5 m, ♂	carpal valgus, CrCd 40° ML 60°, External Rotation 45°
Case 8	Kangal, 57 kg 9.5 m, ♂	CrCd 32°Valgus, ML 40°Procurvatum, External Rotation 30 °
Case 9	Kangal, 21 kg 5.5 m, ♂	CrCd Genu Valgum 30° apex medial Ext Rotat 10°

given to the patient owners, a separate consent document was obtained from each patient.

Animals

After obtaining approval from the Department of Surgery, Faculty of Veterinary Medicine, İstanbul University-Cerrahpasa, we conducted research on 9 dogs of various breeds with deformities in their extremities (8 cases involving the antebrachium and 1 case involving the tibia). Average age was 8 months (range: 5.5-16 months). Only one patient was of mature age. The breed, age, sex, breed and live weight information of the animals are given in *Table 1*.

Preoperative Clinical and Radiographic Evaluation

Preoperative planning included measuring the cranio-caudal and mediolateral angular deformities, rotational deformity, length deficit, as well as determining origin of deformity and assembly of the frame. All patients (6 males and 3 females) having limb deformities were treated using hexapod external fixators with the help of the computer-assisted Spider Frame system.

Animals were sedated with xylazine (Basilazin, Bavet, Türkiye) at a dose of 2 mg/kg by IM route before X-ray. Radiological evaluation of the deformities of all patients was performed using direct craniocaudal and mediolateral radiographs *(Fig. 1)*. CORA (Centre of Rotation of Angulation) angles were calculated by drawing proximal and distal anatomical or mechanical axes in the frontal plane. The Paley criteria, modified according to the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria, were used to evaluate the results

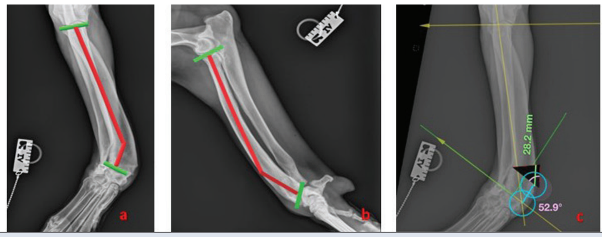

Fig 1. Preoperative radiographs of the Case 7' s antebrachium with lines showing the proximal and distal radial articular surfaces, (a) craniocaudal view and (b) mediolateral view, 90° planes from the articular surfaces and anatomical axes of the radius - CORAs. Determination of the size of the bone fragment to be removed from the radius to correct the deformity (c)

of the deformity treatment as excellent, good, fair, or poor [16,17]. In the ASAMI criteria, excellent scores indicate union, no infection, deformity under 7°, and limb-length discrepancy under 2.5 cm; good scores indicate union and two of the above criteria; fair scores indicate union and only one of the above criteria required of excellent scores; and poor scores indicate non-union, refracture, union and infection, deformity greater than 7°, or limb-length discrepancy over 2.5 cm [16,17].

The Distraction and External Fixator Indices were calculated for all patients. The Distraction Index value was determined by dividing the total length gained by the number of days spent in distraction. The External Fixator Index value was determined by dividing the total duration of fixator application by the total length gained.

Surgical Technique

Preoperative complete blood (cell) count (CBC) and biochemistry values were within normal limits in all cases. Premedication was performed with 0.5-1 mg/kg xylazine HCl (IV), (Basilazin, Bavet, Türkiye), analgesia with 0.1-0.2 mg/kg meloxicam subcutan (SC) (Melox, Nobel Limited, Türkiye), and antibiosis with 25-30 mg/kg ceftriaxone (IV) (Novosef, Sanofi, Türkiye), and general anesthesia was induced with 5 mg/kg ketamine HCl (IV) (Alfamine, Atafen, Türkiye) and maintained with isoflurane 2-2.5% (Forane, Abbott, Italy) and 100% oxygen.

Following general anesthesia and disinfection, joint lines and osteotomy/ostectomy lines were determined based on the CORA points identified during the preliminary measurements. In cases with antebrachial deformity, distal diaphyseal ulna ostectomy was performed initially, followed by the fixation of the first ring in parallel with the proximal joint using the proximal ring as a reference) (*Fig. 2*). Ring diameters, one of the components of the Spider frame, started from 100 mm and increased by 20 mm up to 300 mm. Ring material is made of aluminium alloy. Struts are in 5 different sizes as XXS (70- 95 mm), XS (95- 120 mm), S (120-150 mm), M (140-190 mm) and L (190-300mm). Strut material is made of titanium alloy and stainless steel. During this process, it was ensured that the rings were parallel to the joint and perpendicular to the mechanical axis of the bone. Subsequently, six struts were mounted on the proximal ring, and the distal ring was attached to the antebrachium using K-wires. These struts were then fixed and stabilized to the distal ring. No special effort was made to fix the distal ring parallel to the distal (carpal) joint. Once additional K-wires and Schanz screws were added to each ring to increase stabilization, installation of the Spider Frame was completed. Radial

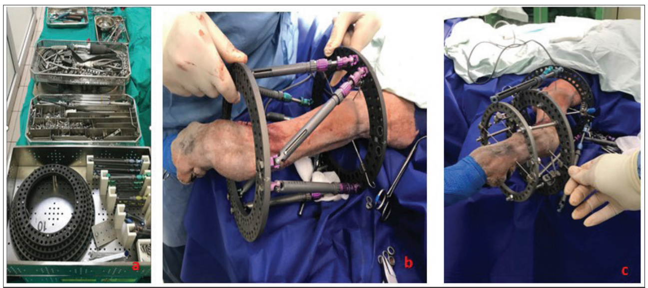

Fig 2. Components of the Spider Frame (a). Installation (b) and final view (c) of the structure of the Computer Assisted Hexapod External Fixator System

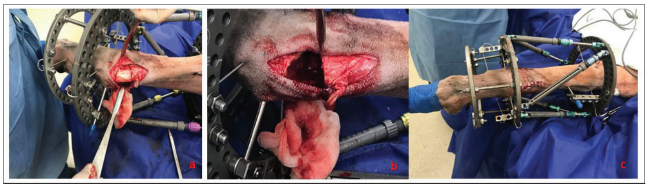

Fig 3. Closed wedge ostectomy was performed with an oscillating saw in the craniolateral approach to the radius with CORA's identified (a). Bone fragment removed from the radius after ostectomy (b). Clinical appearance after correction with spider frame (c)

osteotomy/ostectomy was then performed on the CORA point of the radius (*Fig. 3*). Radial wedge ostectomy was performed on 5 cases that had significant radial procurvatum. When osteotomy/ostectomy of the radius was performed, multiple drilling technique was employed so as to prevent bone warming.

The Spider Frame was fixed, attached and installed in a similar manner when correcting tibial or antebrachial deformities. Particular attention was paid to fixing the proximal ring parallel to the tibia. After installing the Spider Frame, an osteotomy was performed at the CORA point of each case. In order to avoid restricting movement in the stifle joint during the post-operative period, a fixator with a proximal ring diameter of 2/3 was used in the case with tibial deformity. Fixators with wider diameters were preferred for cases with antebrachial deformities.

Immediately following the surgical procedure, radiographs of the craniocaudal and mediolateral planes were obtained for all cases. Ring dimensions, angular deformity values (including angulation, translation, and rotation), and degree of shortening were assessed by means of radiographs. This data was entered into the web-based Spider software to generate prescriptions for correction, as shown in *Fig. 4*. Since all of our cases were owned animals, they were handed over to their owners after the operation and post-operative treatment was recommended. Control examinations were performed by calling our patients at certain intervals. Typically, the length and deformity correction process began on postoperative day 3-5. One week after the start of postoperative correction, radiography was performed to verify the accuracy of the correction, both visually and through software analysis. If residual deformity remained, a re-correction prescription was generated using the software. Struts were then changed under medical supervision. Patients were carefully monitored and treated on a daily basis during hospitalization for correction, wound care, and dressing procedures so that pin-tract infections could be prevented. The correction and extension procedures were followed by a consolidation period that lasted until callus tissue could be radiographically seen from three sides. Once bone union was complete and callus tissue could be

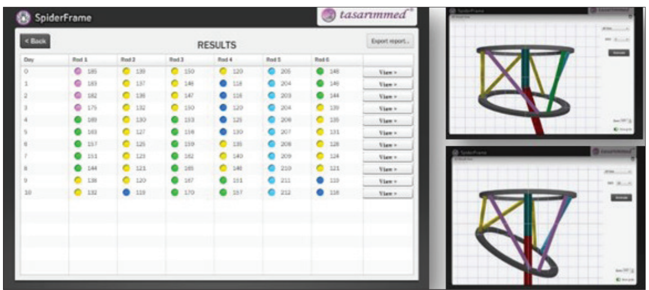

Fig 4. Spider frame correction modes

seen from all three sides, the fixator was removed. Direct input option was preferred while entering data on a daily basis into the Spider Software. This was how deformity corrections were planned and followed.

Assembly of the Spider Frame: It is mandatory to follow the Ilizarov rules. The reference ring can be placed either proximally or distally, but it should be positioned orthogonally to the bone.

If the distal ring is chosen as the reference ring during Spider Frame assembly, it must be applied orthogonally to the bone, that is, it must be perpendicular to the bone in both the anterior-posterior and lateral planes. The letter "A" engraved on the ring denotes the main tab, which should be positioned at the anterior side of the bone to serve as the zero position or reference point for the ring. If sign "A" is placed in any other position, the new position must be entered into the Spider Frame software as the reference ring parameters. The first strut should be placed on the left side of sign "A" when viewed from the front, with numbering continuing in a counterclockwise direction. The connection hole of the first strut on the reference (proximal) ring is marked with two concentric circles, while the counter connection hole is marked with a single circle on the mobile (distal) ring. Then one end of the strut is fixed to the hole with two concentric circles, and the other to the hole with a single circle *(Fig. 5)*.

Capable of solving even the most complex deformity cases, the Spider Frame utilizes the Spiderfix software (Tasarım Medical, Version 2.0.1, İstanbul) *(www.spiderframes.com)*. Of note, this software is designed to work only with Spider Frame rings and struts. Deformity corrections can be planned using Spiderfix software by choosing either of the two options: direct input or measurement. In the direct input option, the user manually enters the calculated data from a printed X-ray image, while in the measurement option, the user can calculate the deformity by drawing some basic lines as in the Picture Archiving and Communication System (PACS) software used in hospitals. When correcting deformities by utilizing the Spider Frame software, one of the three mode types can be used: Daily Mode, Speed Mode, and Advanced Mode.

The Daily Mode, as the name implies, is used for day-based correction, where the user enters the number of days necessary for the deformity to be corrected.

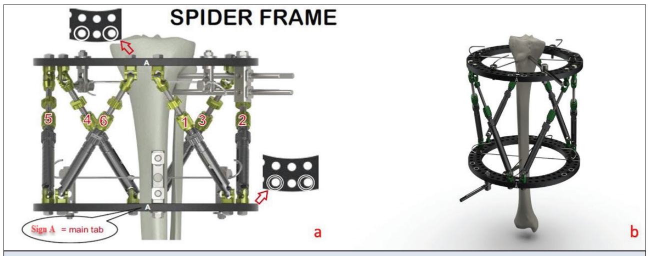

Fig 5. Schematic representation of the spider frame (a,b)

The Speed Mode allows the user to specify the distraction or compression rate, and the duration of correction is calculated by the software based on this user-generated rate.

The Advanced Mode can help correct deformity sequentially by determining the duration of correction for every single deformity type.

Result Window: Calculate button is used for getting results to correct entered deformity by defined frame.

Results

The deformities of 8 cases were located in the radius-ulna and that of 1 case in the tibia.

The cause of the antebrachial deformities was the early closure of the distal ulnar growth plate (carpal valgus) in 8 cases. Deformity in one case was due to the early closure of the lateral proximal tibial plate. Deformities were either oblique (8 cases) or uniplanar (1 case), and all cases suffered from isolated rotational deformities as well as bone shortness.

Average follow-up period was 9.7 months (range: 5-12 months), and mean duration of external application was 74.55 days (range: 53-95 days) *(Table 1)*. Mean bone lengthening was 13.17 mm (range: 6-28.5 mm), with less than 10 mm of lengthening observed in four cases and more than 10 mm in five cases. Gradual correction of deformities was performed in three cases, while six cases

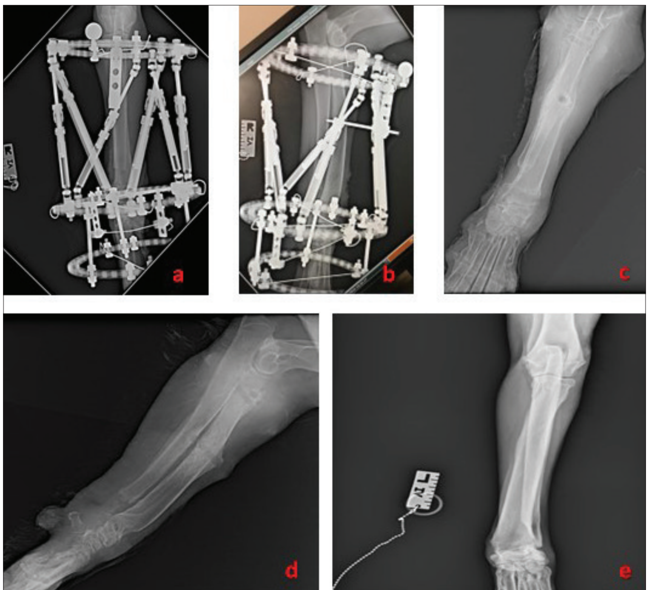

Fig 6. Postoperative radiography before planning the deformity correction of Case 7 (a,b). Craniocaudal and mediolateral radiographs taken after spider removal (c,d). Craniocaudal view of the final radiography of Case 7 (e)

Table 2. *Breef summary of the cases during correction*

Case No	Post- OP after SEF Placed						Distraction Time	Deformity Correction Time	Total Fixator Duration Time
	Angulation			Translation					
	CrCd	Lateral	Axial	CrCd	Lateral	Axial			
1	20°medial angulation	30° cranial angulation	5° external rotation	3 mm medial	6 mm cranial	8 mm shortness	10 D	20 D	55 D
2	Acut Correction No angulation	45° cranial	20° external	Acut Correction No angulation	Acut Correction No angulation	12 mm Shortness	14 D	38 D	95 D
3	Acut Correction No angulation	Acut Correction 10° angulatıon	20° external	Acut Correction No angulation	Acut Correction No angulation	7 mm shortness	7 D	15 D	63 D
4	8° apex	20° cranial	25° external	4 mm medial	Acut Correction No angulation	10 mm Shortness	10 D	23 D	75 D
5	Acut Correction No angulation	15° cranial	Acut correction	5 mm medial	5 mm cranial	12 mm Shortness	13 D	28 D	72 D
6	Acut Correction No angulation	15° cranial	20° external	8 mm medial	3 mm lateral	27 mm Shortness	29 D	35 D	95 D
7	Acut Correction No angulation	No angulation	25° external	3 mm medial	Acut Correction No angulation	28.5 mm Shortness	30 D	35 D	88 D
8	Acut Correction No angulation	15° apex	15° external	3 mm medial	4 mm posterior	6 mm Shortness	6 D	15 D	75 D
9	Gradual Correction 25° apex medial	__	10° external	__	__	8 mm	10 D	15 D	53 D

Table 3. *Results after removal of SPİDER fixator*

Case	After Fixator Removed
Case 1	CrCd angulation was decreased to 7°. Lateral angulation, external rotation, shortness and translation were corrected
Case 2	Lateral angulation was decreased to 20°.CrCd angulation, external rotation, translation and shortness were corrected
Case 3	ML and CrCd angulation,ext-ernal rotation and shortness was totally corrected
Case 4	CrCd angulation,external rotation, shortness and translation were corrected. ML angulation (procurvatum) was decreased to 10°
Case 5	CrCd angulation,external rotation, shortness and translation were corrected. ML angulation (procurvatum) was decreased to 7°
Case 6	Cranial angulation was decreased to 8°. Lateral angulation was decreased to 15°. External rotation, translation and shortness were corrected
Case 7	ML and CrCd angulation,ext-ernal rotation and shortness was totally corrected
Case 8	CrCd angulation,external rotation and shortness were corrected. Lateral angulation (procurvatum) was decreased to 13°
Case 9	CrCd angulation and shortness were corrected

with large procurvatum angles received a certain degree of acute correction on the day of the operation. This was followed by residual correction performed gradually by utilizing the software. Mean Distraction Index was 10.96 d/cm (range: 10-12.5 d/cm), and mean External Fixator Index was 70 d/cm (range: 30.88-125 d/cm). Anguler deformity osteotomy and installation times of spider frame (operation time) were 80, 90, 70, 80, 80, 100, 80, 90, 100, 80, 90, 90, 90 min respectively. Function and cosmesis were preoperatively assessed to be fair to poor in all dogs. Deformity correction started on post-operative day 3-5 and ranged from 0.5 mm to 1.0 mm twice daily. Hospitalization time ranged from 10 to 40 days. After the correction was completed, patients were discharged *(Fig. 6)*.

In the assessment of radio-ulnar correction, the modified Paley criteria, based on ASAMI criteria, were used to evaluate functional and bone results. Bone results were excellent in five cases and good in the rest four

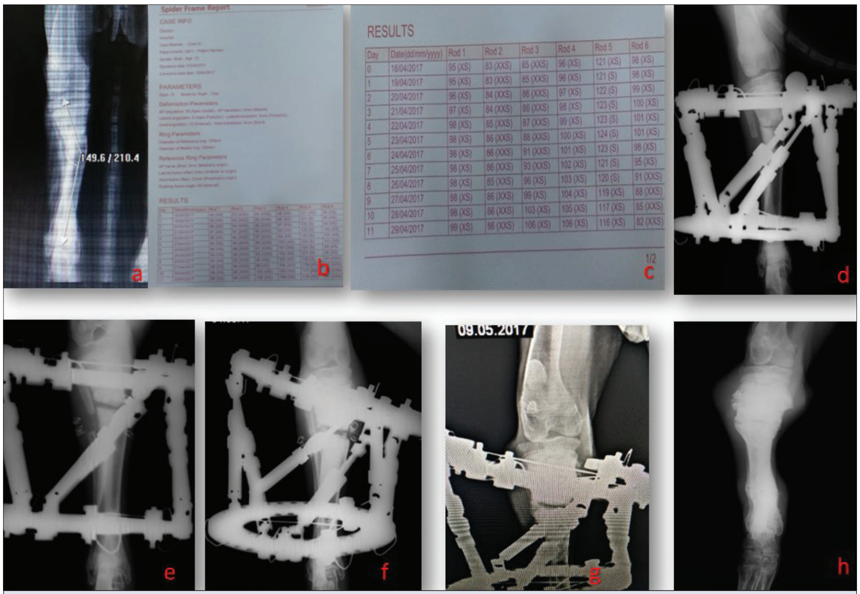

Fig 7. Case 2's clinical view (a) and preoperative Craniocaudal (b) and Mediolateral radiographs (c). Spider frame application (d) and postoperative radiographs are taken (e,f). Radiographs are taken during correction of deformity at 20th days (g,h)

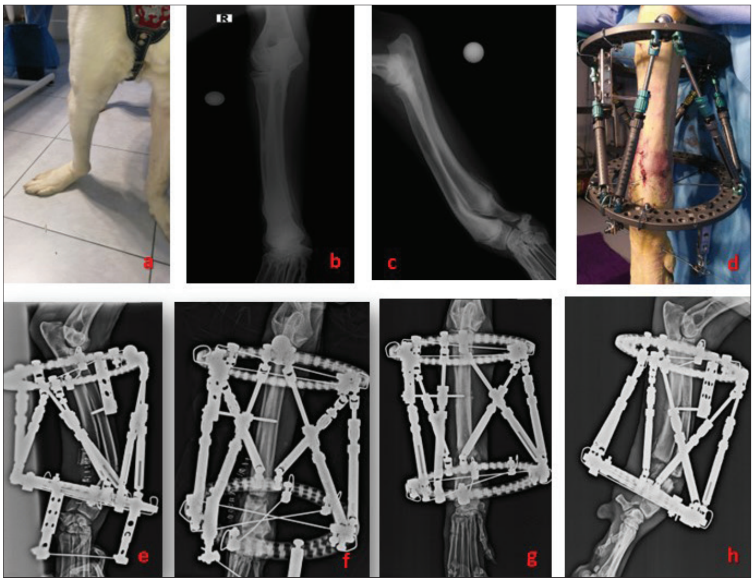

Fig 8. Radiographs of Case 2, Just before removing the frame at 95th days (a,b), Craniocaudal and mediolateral radiographs were taken after removal of the frame (c). Clinical appearance just before (d) and after removal of the spider frame (e)

(Table 2, Table 3). Functional results were excellent in seven cases and good in the rest two *(Table 2, Table 3)*. Long-term cosmesis was good to excellent in all cases. Deformities of 8 cases were in the oblique plane and that of 1 case was in the coronal plane. All cases had isolated shortness and rotational deformity. Mean cranio-caudal angulation (valgus) was 28.5° (range: 18°-40°) and mean lateral angulation was 46.5° (range: 30°-60°) in cases with antebrachial deformity. In the case with tibial deformity the cranio-caudal angulation was 30°, but no lateral angulation was observed *(Fig. 7)*. Mean external rotation angle was 31.67° (range: 10°-70°) in all cases. After the fixator was removed, mean residual cranio-caudal angulation (valgus) was calculated as 7.5° (range: 7°-8°) in two cases, and mean residual lateral angulation (procurvatum) was determined as 13° (range: 7°-20°) in five cases *(Fig. 8, Fig. 9)*. Shortness and rotational deformity were completely corrected in all cases. Superficial pin site infection was observed in most cases but successfully treated by administering local and oral antibiotics as well as by cleaning pin circumference. In two cases (cases 2, 6), a superficial infection developed around the Schanz screws attached to the proximal and distal rings, which did not respond to oral antibiotics. However, following

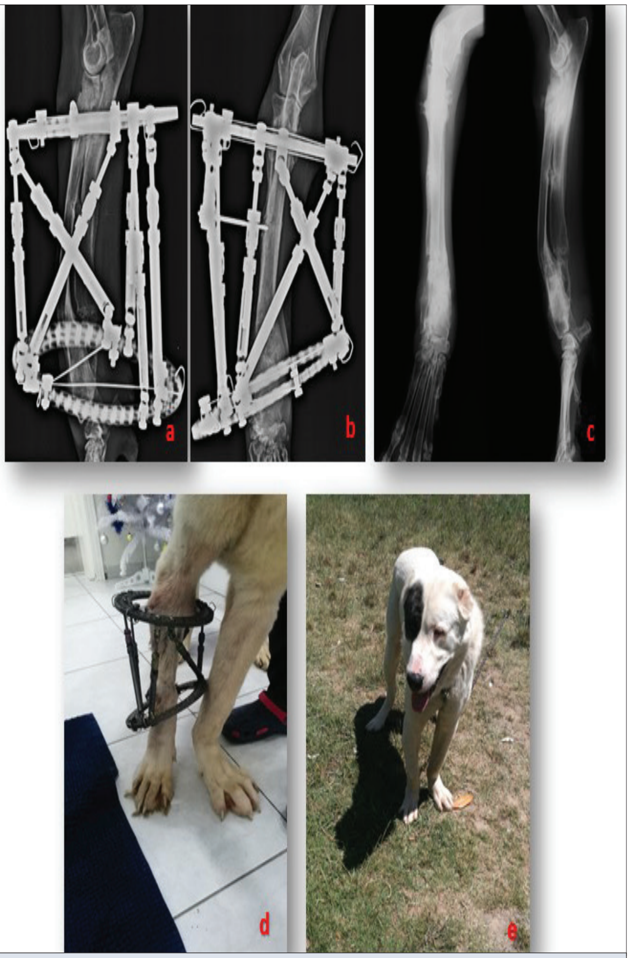

Fig 9. Preoperative Anterio- posterior radiography of the Case 9 (a). Determining the spider frame dimensions by entering the deformity into the system before the operation (b) and preparing the prescription (c). Craniocaudal radiographs taken acute postoperative (d), 8th day (e), 17th day (f), last day of correction (22th day) (g), radiography of the spider frame removed on day 53 (h)

the removal of these screws, the infection resolved during the consultation period. Temporary restriction of range of motion (ROM) in the carpal joint was observed in all cases after the circular fixators were removed. The condition resolved by physiotherapy exercises. Permanent minimal carpal joint restriction was observed in only two cases (cases 4, 6).

Discussion

External fixators are a fundamental method for treating various deformities [18-21]. Results achieved by this method are more than satisfactory; nevertheless, fixator application necessitates strict compliance with certain principles and criteria. For, even the smallest mistake during the planning stage can lead to catastrophic deformities after treatment. Computer-assisted use of circular fixators can help avoid such complications [22].

The mechanical features of the Spider fixators enable the correction of multi-axial deformities. By knowing the lengths of the telescopic rods and diameters of the rings to be used, mathematical calculations can be made to determine where one ring should be placed in relation to another. There are various computer softwares that can serve this purpose and thus provide convenience to the surgeon [23,24]. In this study, we used the Spiderfix, which is a high-tech software that allows for the correction of all deformities simultaneously.

One of the advantages of the Spider system is that the struts of the fixator can be changed without surgery. If the system is assembled properly, residual deformities can be corrected by simply changing struts, without the need for any other modification. This is especially beneficial for patients with oblique plane deformities, since the duration of distraction is shorter in this system than in traditional [25]. Partial correction was achieved in some of our cases. Struts of 6 cases had to be changed because they had greater procurvatum and larger external rotation compared to the others. Of note, all the procedures were performed under clinical conditions.

When Ilizarov or hexapod fixators are applied with proper planning, residual deformity may not occur. It is of paramount importance that if the error rate is to be minimized and permanent residual deformity prevented, the reference ring should be placed orthogonally to the bone segment and completely parallel to the joint [4]. In our cases with antebrachial deformities, the reference (proximal) ring was placed perpendicular to the bone and parallel to the elbow joint without fluoroscopy. In two cases, the deformity was not completely corrected on the desired day. CrCd and lateral X-rays of these cases were retaken, and residual deformities were corrected with the help of the software. In the case with tibial deformity, the proximal ring was selected as the reference ring and placed perpendicular to the tibia and parallel to the knee joint.

There is a relation between how long an external fixation will remain on an extremity and how rigidly it is applied to that area [4]. As well as one Schanz screw, a minimum of two K-wires were applied to each ring, with a view to increasing its stability. There was no loosening between pins and bones in any of our cases, which may be attributed to the rigid placement of the system on the extremity. The rigid assembly of the frame also contributed to its ability to remain on the extremity for a long time. We think that the application of one additional Schanz screw to each ring made it possible for the fixators to be stabilized during the whole period of correction. Of note, fixators applied to our cases remained in place for a mean period of more than 70 days.

An external fixator is a medical device used to immobilize and stabilize bone fragments and is aimed at promoting the healing process. Pin site infections and pin-bone loosening are common complications associated with the use of external fixators, and hexapod fixators are no exception, either. To prevent pin site infections, daily cleaning with Chlorhexidine solution was performed during the postoperative period. Nevertheless, pin site infections developed in three cases, particularly at the location of the pins in the proximal ring, where there is a large muscle mass. These infections were treated with oral antibiotics (cefalexin). The use of at least one Schanz screw per ring was found to increase stability and prevent pin-bone loosening.

The rigid application of the fixator to the extremity ensures proper and radical movement of the distal fragment and associated mobile ring, leading to the correction of the deformity in the desired amount and time. Fixators were applied rigidly in all cases, and no loosening or pin-bone loosening was observed during the course of this study. However, the deformities of two cases were not fully corrected in the initial planning, thus a second planning was required. It may be that the reference ring was not placed perfectly parallel to the joint.

Different hexapod systems have been used in deformity corrections in humans, and it has been reported that mean External Fixator Index shows variations [26]. The reason for this is that there are cases with varying levels of difficulty in which external fixators are used for different durations of time. Mean External Fixator Index in our study was found to be 70 d/cm.

Sakurakichi et al.[27] reported that lengthening of less than 3 cm extended the External Fixator Index. Matsubara et al.[28] reported that Distraction Index and External Fixator Index values of cases undergoing gradual correction was lower than those undergoing acute correction. With a view to correcting the deformity quickly and shortening the duration of fixator use, partial acute correction was performed on six of our cases with severe deformities. The results indicated that mean values of Distraction Index and External Fixator Index were consistent with the literature.

When correcting complex (oblique) deformities, the surgeon must have a certain level of experience with the classic Ilizarov method [29]. The process involving the use of a computer-assisted hexapod system is shorter than the classic Ilizarov technique [30]. This explains the reason why we preferred hexagon external fixators and the Spider Frame software in planning as well as correcting oblique and externally rotated deformities in one single operation. The advantage of this technique is that procedures can be performed in a single-stage fashion and in a shorter time.

Manner et al.[31] stated that, compared to the classic Ilizarov technique, the learning curve for the use of hexapod fixators is shorter; however, success in the latter technique still depends on the surgeon's experience with the former. In the literature, successful outcomes have been reported for bone lengthening through distraction osteogenesis using both the classic Ilizarov method and various hexapod systems [7,32]. The technique of distraction osteogenesis is influenced not only by the osteotomy technique but also by the start day, rhythm, and frequency of distraction [33]. In our study, a daily lengthening of 2x0.5 mm and preservation of the blood vessels in the osteotomy area prevented non-union or delayed union. Swelling was observed in the distal fragment of a few cases with excessive external rotation. This swelling, which resolved spontaneously within one week, was thought to be due to intraoperative partial acute correction.

Although hexapod fixators have certain advantages over the classic Ilizarov external fixators, their high cost is a drawback [34]. Yet, this cost may be overlooked considering that they are easy to use, simple to understand, and have the potential to correct residual deformities.

One of the main limitations of the Ilizarov device is that the frame should be modified and deformities may not be corrected simultaneously with lengthening [35,36]. The Spider Frame actually follows the principles of the Ilizarov device but has several advantages over it [36]. To illustrate, multi-axial deformities can be corrected simultaneously by means of the polyaxial hinges of this device, which render frame modification unnecessary, except for strut changes [37]. In fact, the Spider Frame has the benefit of correcting all deformities at the same time, which saves time [38]. The struts of the Spider Frame are made of titanium alloy, which is lighter and stronger than the stainless steel Ilizarov frames. The Spider Frame software provides an advanced correction mode, which allows the surgeon to choose the ideal correction sequence and duration. For instance, the surgeon may first correct shortness, followed by translation in the CrCd, lateral translation, axial translation, rotation, and finally, angulation. Moreover, the double-sided holes on the surface of the Spider Frame ring provide more flexural strength and connecting holes compared to circular devices.

The Spider Frame also features a threaded locking mechanism to prevent uncontrolled strut movements.

The computer-assisted system allows operators to determine the duration of the deformity correction, making it easier to achieve the desired outcome. Besides, it makes postoperative interventions possible and increases physician confidence.

According to our observations, the only potential disadvantage of the Spider Frame is that the proximal and distal rings are connected to the struts by a poly-axial hinge, which can result in a flexibility of 0.5 mm in the rigidity of the fixator. In contrast, Ilizarov external fixators use fully threaded rods instead of struts, resulting in complete rigidity of the frame. It should be emphasized that the flexibility observed in the Spider Frame may be problematic only in large and giant breed dogs. Of note, we did not encounter any complications in our cases caused by or related to this flexibility. Despite this potential disadvantage, the Spider Frame is a new generation of external fixator systems with many technical advantages and can be recommended for use in appropriate cases.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author (Z. Mutlu) upon reasonable request.

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Conflict of Interest

The authors declared that there is no conflict of interest related to this study.

Author Contributions

Clinical examination of the patients was performed by ZM, MK, YA. Preoperative radiographic measurements and operation were performed by ZM, MK, YA and SSH. Postoperative controls were performed by ZM, MK, YA. The manuscript was written by ZM and YA. YA edited and uploaded the article.

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