Comparison of four surgical methods for pediatric forearm double diaphyseal fractures: a retrospective analysis

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Abstract. – OBJECTIVE: One of the most frequent fractures in children is a double forearm fracture. They make up 26% of children's long bone fractures in the upper extremities and their incidence has increased in recent years. In this study, pediatric patients with double forearm fractures were treated using plate screw, intramedullary K-wire (I-KW), intramedullary titanium elastic nails (TENs), and hybrid fixation (HF) to compare the radiographic and functional results.

PATIENTS AND METHODS: The printed and digital medical records were retrospectively examined from our hospital's archives after receiving consent from the regional ethics committee. Legal guardians of the patients, who were under the age of 18, gave their informed consent. Based on the surgical procedure used, the patients were split into 4 groups. Double plating was the D-P group, hybrid fixation method was the HF group, intramedullary elastic titanium nail was the TEN group, and intramedullary K-wire was the I-KW group. The study comprised 78 patients in total, with 19 patients in the HF group, 21 patients in the TEN group, 20 patients in the I-KW group, and 18 patients in the D-P group.

RESULTS: When the mean operating times of the four approaches were compared, a substantial difference was found. The D-P group's mean operating time (65.2±4.9 minutes) was noticeably longer than those of the other groups (*p*<0.001). The HF group's mean operating time was 55.93.4 min longer than that of the TENs and I-KW groups, which was statistically significant (*p*<0.001). In comparison to the other groups, the D-P group's mean intraoperative fluoroscopy time was considerably shorter (6±3 sec) (*p*<0.001). When compared to the D-P group, it was considerably higher in the HF group (12±2 sec) (*p*<0.001). In comparison to the TENs (20±4 sec) and I-KW groups (19±5 sec), it was significantly lower in the HF group (*p*<0.001). In comparison to the HF group, the D-P group's tourniquet use lasted much longer (*p*<0.001). The TENs and I-KW groups did not use a tourniquet because a mini-incision was made. The D-P group's mean blood loss (110±10 ml) was substantially larger than that of the other groups (*p*<0.001) in the mean blood loss data. In comparison to the TENs (40±5 ml) and I-KW (40±5 ml) groups, the mean blood loss in the HF group (90±10 ml) was considerably larger (*p*<0.001). All patients received an above-elbow postoperative cast. The HF group (2 weeks) and the D-P group (2 weeks) experienced significantly less postoperative immobility than the TENs and I-KW groups (4.4 weeks, *p*<0.001).

CONCLUSIONS: The four fixation techniques used in the current study for juvenile diaphyseal double forearm fractures produced positive clinical and functional outcomes. The hybrid fixation technique was discovered to be comparable to the other techniques and even beneficial in some ways. So, a safe and efficient treatment option for juvenile diaphyseal double forearm fractures is hybrid fixation.

Key Words:
Juvenile diaphyseal, Double forearm fractures, Double plating, Intramedullary K-wire, Intramedullary titanium elastic nails, Hybrid fixation.

Introduction

One of the most frequent fractures in children is a double forearm fracture. They make up 26% of children's long bone fractures in the upper extremities and their incidence has increased in recent years[1]. Boys are more commonly affected than girls[2]. Children's diaphyseal forearm double fractures are often treated with closed reduction and a long-arm plaster cast. Due to its potential to rip the intraosseous membrane between the radius and ulna, forearm double fractures are classified as intra-articular fractures, disrupting the rotational motion of the wrist and elbow joints. However, when there is instability, inadequate reduction, or loss of reduction of these fractures, a nonunion is more likely, and in this case, permanent angulation has been shown to result in decreased forearm rotation and loss of motion[3-8]. Other indications for surgery include multiple trau-

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mas, open fractures, and the development of compartment syndrome[3,4,7]. Restoring axial and rotational stability and enabling a useful range of motion are the objectives of surgery[4,5].

Plate screw and intramedullary fixation are the two surgical procedures most frequently used to repair double fractures of the diaphyseal forearm. These methods include plate screw fixation, intramedullary K-wire, titanium intramedullary elastic nails (TENs), and the hybrid fixation method, which combines plate screw and intramedullary fixation[4,9]. An excellent anatomic reduction, a more stable fixation, and a decent recovery of forearm rotational mobility are all provided by plate screw fixation. However, this method of fixation is associated with complications, such as the need for extensive soft tissue dissection and the risk of soft tissue or nerve damage, the risk of radioulnar synostosis, periosteal damage, along with the potential for infection and re-fracture following plate removal[6-8,10]. Because of these risks, an intramedullary fixation method has been proposed[3,9]. The advantages of intramedullary fixation techniques include fewer incisions, better cosmetic results, less bone periosteum stripping, quicker operations, and simple implant removal[11,12]. However, the intramedullary fixation method also has some disadvantages. Complications such as implant-related skin irritation, a higher number of intraoperative fluoroscopies, nonunion, delayed union, neurovascular injury, and the need for additional immobilization, implant migration, compartment syndrome, and inadequate fixation have been reported compared with plate screw fixation[13-17].

In this study, pediatric patients with double forearm fractures were treated using plate screws, intramedullary K-wire (I-KW), intramedullary titanium elastic nails (TEN), and hybrid fixation to compare the radiographic and functional results. These 4 surgical fixing procedures have been compared only a few times in the literature. Hybrid fixation provides adequate fixation, minimal soft tissue damage, fewer complications, and better radiologic, functional, and clinical outcomes.

Patients and Methods

The printed and digital medical records were retrospectively examined in our hospital's archives after receiving consent from the regional ethics committee. Legal guardians of the patients, who were under the age of 18, gave their informed consent. We performed a power analysis, and the minimum number of patients needed to give the study a high value was determined. The program G*Power 3.1 was used for purposes of the study, and the comparison of four surgical methods for double diaphyseal fractures of the pediatric forearm, the subject of our study, was calculated by theoretical power analysis using a *t*-test, such that a total of at least 72 patients had to be included, with at least 18 patients in each group[18]. All patients' written and digital records were examined. 83 individuals with a double diaphyseal forearm fracture who underwent surgery between 2012 and 2020 were thus included in the study. They ranged in age from 8 to 16 years.

Criteria for inclusion were:

1) Patients between the ages of 8 and 16.
2) Patients suffering from a diaphyseal fracture of the middle 1/3 of the forearm.
3) >10° angulation in the anteroposterior or lateral plane after closed reduction.
4) >30° malrotation after closed reduction.
5) Translation of more than half the bone diameter after closed reduction.
6) Patients with a normal preoperative neurovascular examination.
7) A follow-up period of more than 18 months.

Exclusion criteria:

1) Patients older than 16 and younger than 8 years old.
2) Associated fractures or dislocations of the upper extremities.
3) Pathological fractures.
4) Open fractures.
5) Patients with neuromuscular diseases.
6) Patients with neurovascular injuries.
7) Concurrent damage to vital organs.
8) Complex fractures of the forearm (Monteggia fracture, Galeazzi fracture, intra-articular elbow fracture or distal radius fracture).

When all data were collected, 5 patients were excluded. For 3 of these patients, there was insufficient documentation. One patient had a concomitant humeral fracture. One patient had a preoperative neurovascular injury.

Based on the surgical procedure used, the patients were split into 4 groups. Double plating was the D-P group, hybrid fixation method was the HF group, intramedullary elastic titanium nail was the TEN group and intramedullary K-wire was the I-KW group. The study comprised 78 patients in total, with 19 patients in the HF group, 21 patients in the TEN group, 20 patients in the I-KW group, and 18 patients in the D-P group.

In addition to demographic information, the Orthopaedic Trauma Association (OTA)[19] classification system for diaphyseal forearm fractures was used to categorize the type of fracture, side of the injury, mechanism of injury, length of the incision, number of intraoperative fluoroscopies, time spent using the tourniquet, estimated blood loss, and fixation method. At successive follow-up appointments, the number of complications, length of fracture healing, final range of motion, and functional outcomes for the postoperative period were evaluated and recorded. The occurrence of non-union, malunion, or other potential problems was noted. Bridging callus in three of the four cortices on two orthogonal films was the criteria for determining if a fracture had healed. According to Schmittenbecher's definition[20], a nonunion lasting more than 3 months was referred to as a "delayed union", and a nonunion lasting more than 6 months was referred to as a "nonunion".

Operative Technique

All patients had surgery in the supine position, under general anesthesia. Patients were wrapped with a tourniquet. In patients with reduction, no tourniquet was applied. In patients with open reduction, the tourniquet was applied. The tourniquet pressure was set between 150-250 mmHg as blood pressure x 2 ± 25.

For fixation of the ulna in double plate fixation, the forearm was entered from the dorsomedial forearm with a direct approach and the skin was passed subcutaneously. The ulnar fracture was achieved *via* an approach between the FCU and ECU tendons. The fracture ends were mobilized with a curette, and fracture reduction was performed. The fracture was then fixed by insertion of a dynamic compression plate and appropriate screws. The adequacy of the reduction was checked with the endoscope. After the bleeding stopped, the opened folds were properly closed after washing with ample SF. Next, the radius was approached. Using the standard anterior Henry approach, the dermal subcutaneous fascia was traversed through an incision on the volar side of the forearm. The muscles extensor digitorum and extensor carpi radialis brevis were transected. The posterior interosseous branch of the radial nerve and the radial artery were found and protected. The supinator muscle was detached from the bone and the fracture was reached. After the fracture ends were revitalized with a curette, the fracture was fixed by applying a dynamic compression plate and screws after fracture reduction. The adequacy of the reduction was checked using the endoscope. After the bleeding stopped, the opened folds were properly closed after washing with copious SF. After receiving surgical care, all patients were required to wear a long-arm plaster splint for two weeks.

For intramedullary fixation, an incision was made over the styloid radialis in the distal forearm, and the subcutaneous fascia was crossed. The radial nerve's superficial branch was located and safeguarded. The distal end of the radius was reached. The radial physis was traced by fluoroscopy and a borehole was made. An intramedullary K-wire (I-KW) or an elastic titanium intramedullary nail (TEN) was inserted proximally into the radius to traverse the fracture line. When the fracture line was reached, the fracture was reduced by traction and manipulation proximal to the fracture line. If reduction failed, the fracture line was opened with a mini-incision and manual reduction was performed. Subsequently, the ulnar fracture was treated. After opening the entrance hole with an olecranon drill for the ulna posterior of the elbow, I-KW or TEN were passed through the medullary canal of the ulna. After the fracture line was reduced with an endoscope, it was sent towards the distal.

Scopy showed good reduction. Following bleeding control, the opened folds were duly closed after washing with copious SF. All patients underwent long-arm plaster splinting after surgical treatment.

With hybrid fixation, an intramedullary nail was used for radius fixation. In the distal forearm, an incision was made over the radial styloid and the skin subcutaneous fascia was crossed. It was possible to locate and safeguard the superficial branch of the radial nerve. The distal end of the radius was reached. After the radial physique was found with the help of fluoroscopy and an entry hole was opened with the help of a drill just above it, titanium intramedullary elastic nails (TENs) were sent intramedullary towards the proximal part of the radius, crossing the fracture line. In order to send the fracture to the proximal of the fracture line, it was decreased by traction and manipulation with the use of a scope when it reached the fracture line. If the reduction failed, the fracture line was opened with a mini-incision, and manual reduction was applied. Then, the ulnar fracture was treated. Open reduction was performed for the ulnar fracture. The dorsomedial forearm was entered with a direct approach, and skin-subcutaneous was passed. The ulnar fracture was reached by entering between the FCU and ECU tendons. After the fracture ends were revitalized with a curette, fracture fixation was performed by placing a dynamic compression plate and screws appropriately following fracture reduction. Fluoroscopy showed that the reduction was complete. Following bleeding control, the opened folds were closed properly after washing with plenty of SF. All patients received a long arm plaster splint for two weeks following surgery.

Every other day, patients were given new clothes. Antibiotics were given as a preventative measure, along with painkillers. Early physiotherapy intervention was undertaken. Patients were contacted for follow-up visits at 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months, and 1 year to assess postoperative wound care and union and to follow up on radiologic and functional findings.

Functional outcomes from the most recent follow-up examination were assessed using Price's criteria. As a result, the results were rated as follows: excellent (no complaints with strenuous physical activity or loss of pro-supination 10°), good (mild complaints or loss of forearm rotation 11-30° with strenuous physical activity), fair rating (subjective complaints during daily activities or loss of forearm rotation 30-90°), and poor (all other results)[21]. By comparing it to the rotation in the unaffected forearm, the loss of rotation in the affected forearm was identified.

Statistical Analysis

The statistical analysis was performed using SPSS (Statistics for Windows), version 20.0, (IBM Corp., Armonk, NY, USA). Mann-Whitney U with Bonferroni correction was utilized due to the four distinct groups. Continuous data were expressed as mean and standard deviation, whereas categorical data were expressed as frequencies and percentages. A *p*-value below 0.05 was considered statistically significant.

Results

Demographic information, fracture classification, side, and injury mechanism are shown in Table I. Between the groups, there was no statistically significant difference.

Standard surgical practices were followed when operating on the patients. In the hybrid treatment group, titanium intramedullary elastic nails were used to treat the radius fracture, and plate screws were used to repair the ulna fracture. A titanium intramedullary elastic nail placed on the radius prevents radial bowing, while a more secure plate-screw fixation in the ulna controls forearm rotation. This lessens the dissection of soft tissue and may lessen the chance of refracture brought on by implant removal.

Intraoperative parameters of the groups are shown in Table II. When the mean operating times of the four approaches were compared, a substantial difference was found. The D-P group's mean operating time (65.2±4.9 minutes) was noticeably longer than those of the other groups ($p<0.001$). The HF group's mean operating time was 55.9±3.4 min longer than that of the TENs and I-KW groups, which was statistically significant ($p<0.001$). The difference between the

Table I. General characteristics and demographic data of groups.

	HF	D-P	TENs	I-KW	*p*
Age	11.5±2.1	12.1±1.9	10.8±2.2	10.9±2.1	0.976
Gender	Male: 11	Male: 10	Male: 11	Male: 9	0.713
	Female: 8	Female: 8	Female: 10	Female: 11	
Affected limb side	Right: 7	Right: 10	Right: 9	Right: 19	0.246
	Left: 12	Left: 8	Left: 12	Left: 7	
Fracture classification AO classification	22-A: 10	22-A: 7	22-A: 10	22-A: 11	0.624
	22-B:6	22-B:6	22-B:7	22-B:7	
	22-C:3	22-C:5	22-C:4	22-C:2	
Injury mechanism	Simple fall: 16	Simple fall: 14	Simple fall: 19	Simple fall: 17	0.655
	High-energy trauma: 3	High energy trauma: 4	High-energy trauma: 2	High-energy trauma: 3	
Cast treatment history	Yes: 16	Yes: 15	Yes: 19	Yes: 17	0.832
	No: 5	No: 3	No: 2	No: 3	

HF: Hybrid fixation, D-P: Double plating, TENs: intramedullary elastic titanium nail, I-KW: intramedullary K-wire.

Table II. Intraoperative parameters of the groups.

	HF	D-P	TENs	I-KW	*p*	
Operation time (minutes)	55.9±3.4 min	65.2±4.9 min	40.8±6.2 min	41.1±5.3 min	<0.001	2>1>3=4
Incision length (cm)	9.3±1.6 cm	13.1±1.4 cm	4.2±0.8 cm	4.7±0.6 cm	<0.001	2>1>3=4
Fluoroscopy time (sec)	12±2	6±3	20±4	19±5	<0.001	3=4>1>2
Tourniquet time (minutes)	25±5 dk	45±3 dk	0	0	<0.001	2>1>3=4
Mean blood loss (ml)	90±10 ml	110±10 ml	40±5 ml	40±5 ml	<0.001	2>1>3=4

HF: Hybrid fixation, D-P: Double plating, TENs: intramedullary elastic titanium nail, I-KW: intramedullary K-wire.

TENs group (40.8±6.2 min) and the I-KW group (41.1±5.3 min) was not statistically significant (p=0.876). Between the four procedures, there was a statistically significant variation in the length of the incision. In comparison to the TENs (4.2±0.8 cm), I-KW group (4.7±0.6 cm), and D-P group (13.1±1.4 cm), the mean incision length was substantially larger in the D-P group. Additionally, the HF group's incision length was noticeably longer than that of the TENs and I-KW groups (p<0.001). The TENs group and the I-KW group did not differ statistically significantly from one another (p=0.924). In comparison to the other groups, the D-P group's mean intraoperative fluoroscopy time was considerably shorter (6±3 sec) (p<0.001). When compared to the D-P group, it was considerably higher in the HF group (12±2 sec) (p<0.001). In comparison to the TENs (20±4 sec) and I-KW groups (19±5 sec), it was significantly lower in the HF group (p<0.001). Between the TENs group and the I-KW group, there was no statistically significant difference (p=0.762). In comparison to the HF group, the D-P group's tourniquet use lasted much longer (p<0.001). The TENs and I-KW groups did not use a tourniquet because a mini-incision was made. The D-P group's mean blood loss (110±10 ml) was substantially larger than that of the other groups (p<0.001) in the mean blood loss data. In comparison to the TENs (40±5 ml) and I-KW (40±5 ml) groups, the mean blood loss in the HF group (90±10 ml) was considerably larger (p<0.001).

All patients received an above-elbow postoperative cast. The HF group (2 weeks) and the D-P group (2 weeks) experienced significantly less postoperative immobility than the TENs and I-KW groups (4.4 weeks, p<0.001).

The postoperative and clinical characteristics of the groups are shown in Table III. With no statistically significant difference across groups (p=0.782), the mean follow-up period was 24.1±2.7 weeks in the D-P group, 26.1±3.0 weeks in the TEN group, 26.2±2.8 weeks in the I-KW group, and 25.8±2.0 weeks in the HF group. Radius and ulna cross-linking times did not differ statistically significantly between the four procedures (p=0.326). No patient in either group had fracture sites that had residual angulation, translation, or malrotation. No nonunion cases were reported.

Table III. Postoperative and clinical characteristics of the groups.

	HF	D-P	TENs	I-KW	*p*
Follow-up period (weeks)	25.8±2.0 w	24.1±2.7 w	26.1±3.0 w	26.2±2.8 w	0.782
Bone union time (week)	10.1±2.4 w	9.5±2.1 w	11.2±1.4 w	11.6±1.2 w	0.326
Functional results	Excellent: 13 Good:5 Fair:1 Poor: 0	Excellent: 12 Good:4 Fair:2 Poor: 0	Excellent: 14 Good:5 Fair:2 Poor: 0	Excellent: 13 Good:5 Fair:2 Poor: 0	0.822

HF: Hybrid fixation, D-P: Double plating, TENs: intramedullary elastic titanium nail, I-KW: intramedullary K-wire.

Table IV. Comparison of groups in terms of postoperative complications.

	HF n:19	D-P n:18	TENs n:21	I-KW n:20	*p*
Superficial infection	3 (15.8%)	3 (16.7%)	1 (4.8%)	1 (5%)	
Soft tissue irritation	1 (5.3%)	0	2 (9.5%)	3 (15%)	
Refracture	0	1 (5.6%)	0	0	
Delayed union	0	0	1 (4.8%)	0	
Total	4 (21.1%)	4 (22.2%)	4 (19.1%)	4 (20%)	0.966

HF: Hybrid fixation, D-P: Double plating, TENs: intramedullary elastic titanium nail, I-KW: intramedullary K-wire.

All the study's subjects had at least a 12-month follow-up period. The results obtained at the most recent follow-up according to Price's criterion did not statistically differ across the four procedures (p=0.822) (Table III).

A comparison of groups in terms of postoperative complications is shown in Table IV. In terms of problems, there was no statistically significant difference between the groups (p=0.966). Soft tissue irritation occurred in 1 patient (5.3%) and 3 patients (15.8%) in the HF group, respectively. A combination of daily dressings and antibiotherapy were used to treat superficial infections. The removal of the intramedullary titanium elastic nail alleviated symptoms in patients with soft tissue irritation. Three (16.7%) patients in the D-P group experienced superficial infections, and one (5.6%) experienced refracture. A combination of daily dressings and antibiotherapy were used to treat superficial infections. At week 3, after implant removal, one patient experienced a fracture brought on by a fall from the arm, which required surgical intervention. One patient (4.8%) in the TENs group experienced a superficial infection, two (9.5%) experienced soft tissue irritability, and one (4.8%) experienced a delayed union. A combination of daily dressings and antibiotherapy were used to treat superficial infections. Soft tissue irritation in these cases was brought on by the titanium elastic intramedullary nail protruding through the entry sites into the skin, and the issue was resolved by removing the titanium elastic intramedullary nail following union. One patient's late union was brought about by insufficient fixation. At postoperative week 14, a 16-year-old patient showed signs of union, and no additional treatment was necessary. One patient (5%) in the I-KW group experienced a superficial infection, while three patients (15%) experienced soft tissue irritation. A combination of daily dressings and antibiotherapy were used to treat superficial infections. When the K-wire was taken out, the issue with the soft tissue irritation was resolved.

Discussion

The results reported by this present study show that hybrid fixation is a method that utilizes the advantageous aspects of hybrid fixation, leaving out the disadvantages aspects in comparison to the other three groups. These disadvantages, such as long operation time, long incision, intraoperative blood loss, and radial nerve damage, were reduced. Disadvantages such as prolonged intraoperative fluoroscopy, prolonged postoperative immobilization, delayed union, and pseudoarthrosis of the ulna or prolonged time to bone union, which were seen in the other 2 groups using the intramedullary fixation method, were found to be less common with the hybrid fixation method.

One of the most frequent upper extremity injuries in children is a double forearm fracture[22]. Most forearm double fractures in this age group are successfully treated with closed reduction and plaster splints; however, there are some instances when closed reduction is insufficient and unreliable. In these cases, surgical treatment may be required[14]. Especially in children older than 10 years, there is more predilection towards surgical treatment of pediatric forearm fractures in this age group because of the lower remodeling potential[4,23]. However, it is still a matter of debate which fixation procedure is most appropriate for this age group. The intramedullary fixation method is often preferred due to its successful aspects. These include the use of a mini-incision through which only the implant is inserted, the shortened operation time, the fact that the fracture line does not need to be opened, or the minimal dissection of the fracture line[11,12,15]. The intramedullary fixation technique has been linked to complications like infection at the entry site, skin irritation from the implant, failure to fix the implant, implant migration, failure of the implant to pass through the medullary canal, tendon injury at the entry site, compartment syndrome, pseudoarthrosis of the ulna, and delayed union, according to recent studies[17,20]. Additionally, numerous studies[23,24] have demonstrated that children older than 10 years are more likely to experience intramedullary fixation difficulties. In their investigation, Flynn et al[22] found that intramedullary fixation may not be adequate and that open reduction is frequently necessary, especially in patients older than 10 years. According to Martus et al[25], patients above the age of ten were more likely to experience TEN-related problems than patients under the age of ten.

Previous studies[20,26,27] have shown that pediatric forearm fractures treated with intramedullary fixation are more vulnerable to ulnar union problems. Krohn[27] reported that patients with pediatric forearm double fractures treated with anterograde TEN fixation to the ulna frequently experienced ulnar union problems due to angulation between the fracture ends. In this study, patients with pediatric forearm double fractures treated with retrograde TEN fixation to the radius had fewer problems with bone union, due to impingement at the fracture ends than at the ulna[27]. Complication rates ranging from 16.4% to 50.0% have been reported in patients with intramedullary fixation of pediatric double forearm fractures[11,15,17,20,25,26]. In our study, this rate was 19.1% in the TEN group and 20.0% in the I-KW group.

After exposing the fractures in both bones by two different incisions, the open reduction and internal fixation approach relies on adequate reduction and proper implant placement. The primary benefit of this surgical method is that it completely controls fracture reductions both axially and rotationally while reconstructing the radius's bending. Accordingly, proper pronation and supination movement is achieved by regulating the movements between the radius and ulna, which allows us to achieve good functional results[6-8]. The disadvantages of plate-screw fixation are that it requires extensive soft tissue dissection to ensure proper reduction and adequate fixation and has complications such as the risk of soft tissue or nerve damage, the risk of radioulnar synostosis, periosteal damage due to stripping of the bone periosteum, and the risk of re-fracture and infection after plate removal[10,28]. In the literature, the complications of plate-screws for pediatric forearm diaphyseal fractures were reported at rates of 28% and 33%, while it was 22.2% in patients with plate-screw fixation in this study[28,29].

By combining some of the advantages of plate-screw fixation with some of the problems of intramedullary fixation, hybrid fixation was developed. For the ulna fracture, a plate-screw fixation method was used, and for the radius fracture, a titanium intramedullary elastic nail fixation method was used. Compared to TENs fixation and plate-screw fixation, hybrid fixation has advantages. Potential drawbacks are reduced such as prolonged operations, lengthy incisions, significant intraoperative blood loss, and radial nerve injury brought on by double plating. Hybrid fixation was reported to have fewer drawbacks in the other two groups when intramedullary fixation was employed, including increased intraoperative fluoroscopy use, prolonged postoperative immobilization time, late union and pseudoarthrosis of the ulna, or prolonged bone union time. When compared to patients with double plate fixation, Zheng et al[30] found that patients with hybrid fixation had shorter incisions and shorter surgical times. They noted that patients with titanium intramedullary elastic nails experienced fewer intraoperative fluoroscopies and shorter postoperative immobilization times. According to Zhu et al[31], patients with hybrid fixation required less time for surgery and more time for fluoroscopy than patients with double plate fixation. According to the findings of our study, which were supported by the literature, the hybrid group's incision and procedure times were shorter than those of the double plate group. As a result, hybrid fixation can be suggested as an effective surgical treatment option in pediatric double diaphyseal fractures of the forearm.

According to Feng et al[32], patients who had titanium intramedullary elastic nail fixation experienced considerably slower ulna union than those who underwent hybrid fixation. In comparison to the hybrid and double plate groups, the titanium intramedullary elastic nail fixation group had a decreased three-month ulna union rate, according to Zheng et al[30]. The union times in the I-KW and TENs groups were not statistically different from those in the other two groups in our study.

In the literature, there was no statistically significant difference in functional outcomes between the titanium intramedullary elastic nail groups, double plate groups, and hybrid fixation groups[30-35]. There was no discernible difference between the groups in our study's functional outcomes (p=0.822). Between the four fixation groups, there was no statistically significant difference in the rate of complications (p=0.966). When all of these facts are taken into consideration, hybrid fixation can be employed as a secure and reliable treatment for pediatric double diaphyseal fractures of the forearm.

Limitations

The present study has some limitations, most notably its retrospective methodology and the small number of cases, which reduced the study's ability to conduct statistical analysis. There have been very few attempts to provide standardized evaluations of bone union in a retrospective investigation[36,37]. Larger, randomized controlled studies may provide more reliable clinical evidence in the future. Furthermore, factors influencing implant choice cannot be identified from retrospective investigations of orthopedic trauma. Fracture pattern, soft tissue involvement, and surgeon familiarity with implants may introduce inherent selection bias that could potentially influence outcomes.

Conclusions

The four fixation techniques used in the current study for juvenile diaphyseal double forearm fractures produced positive clinical and functional outcomes. The hybrid fixation technique was discovered to be comparable to the other techniques and even beneficial in some ways. Thus, a safe and efficient treatment option for juvenile diaphyseal double forearm fractures is hybrid fixation. However, we think that the optimal treatment is not determined only by the characteristics of the fracture and the age of the patient. We believe that our results should be supported by extensive studies.

Conflict of Interest

The Authors declare that they have no conflict of interest.

Funding

None.

Informed Consent

The authors declare that the patients included in the study signed informed consent forms to use their medical information in the studies.

Ethics Approval

The printed and digital medical records were retrospectively examined in our hospital's archives after receiving consent from the Regional Ethics Committee of Malatya Turgut Özal University (Approval no: 2022/12-305).

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