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Treatment Outcomes of Adolescent AO 22A Diaphyseal Radius and Ulna Fractures Treated with Dynamic Compression Plate and Intramedullary Elastic Nail

Ahmad Humayun Sarfraz[1], Bilal Mukhtar[2], Asma Akram[3], Asad Ali[4], Asif Hanif[5], Faisal Masood[6]

ABSTRACT

Background & Objective: Diaphyseal fractures of the forearm are a prevalent orthopedic injury that necessitate surgical intervention to reestablish functional range of motion, alignment, and stability. Complications, including malunion, nonunion, and long-term functional impairment, may result from these fractures if not properly managed. Main Objective was to compare treatment outcome of Adolescent AO 22A Diaphyseal Radius and Ulna Fractures Treated with Dynamic Compression Plate and Intramedullary Elastic Nail.

Methodology: It was a prospective comparative study that included 70 patients, all of whom had diaphyseal fractures of the radius and/or ulna that necessitated surgical treatment. The patients were aged between 12 and 18 years. Group A consisted of 35 patients who were treated with DCP fixation, while Group B consisted of 35 patients who were treated with IMEN fixation. The patients were randomly assigned to these two categories. Clinical evaluations were conducted at 2 weeks, 6 weeks, and 12 to 16 weeks following surgery to evaluate pain levels, functional improvement, range of motion, and any complications.

Results: At 6 weeks, Group B (IMEN) showed better outcomes with lower Quick DASH (15.49 ± 2.94 vs. 20.45 ± 2.99) and higher MEPS (81.6 ± 4.8 vs. 75.3 ± 5.2), with faster union (10.8 ± 1.9 vs. 12.5 ± 2.3 weeks, $p<0.05$). By 12–16 weeks, functional recovery remained superior (MEPS 91.2 ± 3.9 vs. 85.7 ± 4.3; Quick DASH 8.5 ± 1.4 vs. 12.6 ± 1.9, $p<0.05$). Complications were fewer in Group B (infection 2.9% vs. 8.6%, malunion 0% vs. 5.7%).

Conclusion: This study shows that Intramedullary Elastic Nailing (IMEN) provides superior outcomes over Dynamic Compression Plate (DCP) fixation in diaphyseal forearm fractures, with faster healing, improved function, less pain, and fewer complications. Both methods remain effective, but IMEN may be preferred in adolescents, while larger studies with longer follow-up are needed for confirmation.

KEY WORDS: Intramedullary Elastic Nailing, Dynamic Compression Plate, forearm fractures, functional outcomes, bone healing, complications

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INTRODUCTION

Despite its low incidence of 1–10 per 10,000 per year, adolescent forearm fracture, particularly diaphyseal fractures of the radius and ulna, are the most common orthopedic injuries.[1] They cause more than 30 percent of the upper extremity fractures and 3 to 6 percent of all adolescent fractures, excessively effecting males.[2] Its primary causes are falls, road accidents and direct trauma; in Pakistan children have a prevalence of "7.7%" and adolescents "5.31%".[3]

Due to the developing skeletal, treatment is critical because inadequate healing cause defect in developing new bones and impair performance of existing limbs.[4] Surgery is required to fix unstable or displaced fractures.[5] Dynamic Compression Plate (DCP) fixation offers firm stability and alignment but has drawbacks that include soft tissue damage, periosteal damage, synostosis, neurovascular dysfunction and nonunion in the aftermath of the plate removal operation.[6] The intramedullary nailing option on the other hand has become more popular, as it does not remove the periosteum or soft tissues and also reduces the operating complications and duration of surgery.[7] However, it also requires a second operation to remove nails, immobilization after surgery and risk of growth plate damage besdie the epiphysis.[8] Currently, little information exists that directly compares DCP and Intramedullary Elastic Nails (IMEN) among adolescents; however, they are commonly used. Even though previous studies show that both methods result in attaining union and functional recovery, a dispute exists regarding their superiority.[1] IMEN is less invasive, the implants must be removed and there is still a risk of tissue in its growth components[9], but has a shorter recovery time than DCP, which offers superior stability, but with more soft tissue issues.[10] Due to the lack of local comparative studies, the present study comparatively evaluates the radiographic union, functional outcomes and chances of complication in DCP and IMEN among adolescent AO.[11] A forearm fractures in order to determine the optimal course of treatment.

Correspondence:
Ahmad Humayun Sarfraz[1]
AP Department of Orthopedic
KEMU, Lahore

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METHODOLOGY

Study Design: Randomized control trial (RCT)

Study Setting: The study was performed at the Orthopedic Department Unit 1, Mayo Hospital, King Edward Medical University, Lahore, Pakistan

Study Duration: The study was conducted over six months starting immediately after the research synopsis was approved.

Sample size: A total of 70 patients were included, calculated using standard statistical formulae with a 95% confidence level, 8% absolute precision, and expected functional outcome proportions of 98% for DCP and 96% for IMEN based on previous studies.[11] The sample was equally divided into two groups: Group A (DCP fixation, n=35) and Group B (IMEN fixation, n=35). The formula applied was:

$$\frac{Z^2_{1-a/2}[P_1(1-P_1)+P_2(1-P_2)]}{d^2}$$

where n = sample size (70), Z = 1.96 at 95% CI, $P_1 = 0.98$, $P_2 = 0.96$, and d = 0.08.

Sampling Technique: The study used a non-probability simple random sampling technique.

Sample selection criteria

Inclusion Criteria:

- Patients aged between 12 and 18 years of either gender who presented within 24 hours of injury, based on history and clinical examination.
- Patients diagnosed with closed fractures of the shafts of both the radius and ulna, confirmed through history, clinical evaluation, and radiographic findings

Exclusion Criteria:

- Patients with open fractures classified as Gustilo Anderson type 3A, fractures other than simple diaphyseal radius and ulna fractures, and those with comorbid conditions.
- Additionally, patients with multiple fractures, neurovascular injury, isolated fractures of either the radius or ulna, recurrent fractures, or pathological fractures, as determined by history, clinical examination, and radiographs, were excluded from the study.

Data Collection Procedure

Following ASRB/ERC approval and written informed consent (with the right to withdraw), eligible adolescents (10–19 y) with closed diaphyseal radius/ulna fractures (AO 2U2A1–A3, 2R2A1–A3) were randomized by lottery to Group A(DCP) or Group B (IMEN). Group Aunderwent volar/dorsal plating (6–8-hole DCP) with immediate mobilization; Group B received elastic intramedullary nails under fluoroscopy with a 3-week above-elbow slab then exercises.

In this study, adolescents were defined as individuals aged 10–19 years, and diaphysis referred to the central shaft of long bones. A closed diaphyseal fracture of the radius and ulna was considered when the fracture occurred in the shaft without skin penetration and was classified according to the AO system (2U2A1–A3, 2R2A1–A3). Union was defined as healing with callus bridging at least three cortices on radiographs, while delayed union was failure to unite by 6 months, and nonunion was absence of healing for three consecutive months after 9 months. Functional outcomes were assessed by range of motion and strength, graded as excellent, satisfactory, unsatisfactory, or failure. Fixation methods included Dynamic Compression Plates (DCP) providing rigid stabilization and Intramedullary Elastic Nails (IMEN) offering flexible intramedullary fixation. Follow-up occurred at 2, 6, and 12 weeks, then 3-monthly, assessing radiological union, functional recovery, and complications (infection, malunion/nonunion, hardware issues). Data were analyzed using descriptive statistics (mean ± SD for quantitative variables; frequencies and percentages for categorical data) and inferential tests. Independent t-tests compared healing time and functional recovery, while chi-square tested associations in complications, with $p<0.05$ as significant. Primary outcomes included time to radiographic union and functional recovery, and secondary outcomes included complication rates. Results were presented in tables and graphs, showing significantly faster healing, better function, and fewer infections in IMEN compared to DCP, with higher overall patient satisfaction.

RESULTS

The demographic and clinical profile of patients was comparable across both groups. The mean age was 14.2 ± 2.1 years in Group A and 13.8 ± 1.9 years in Group B (p=0.42). Males predominated in both groups (62.9% vs. 65.7%, p= 0.80). Right-sided fractures were slightly more common overall (57.1%), but the side distribution did not differ significantly between groups (p=0.62).

Patients treated with IMEN achieved radiographic union significantly earlier compared to those treated with DCP. The mean time to union was 10.8 ± 1.9 weeks in Group B versus 12.5 ± 2.3 weeks in Group A, with the difference being statistically significant (p=0.004, independent t-test). The average time required to regain full range of forearm pronation and supination was also shorter in Group B (12.1 ± 2.4 weeks) compared to Group A (14.3 ± 2.8 weeks), with the difference again statistically significant (p=0.003, independent t-test). At the 6th week follow-up, patients in Group B demonstrated significantly higher MEPS scores (81.6 ± 4.8) compared to Group A (75.3 ± 5.2, $p<0.001$), reflecting superior elbow function. QuickDASH scores were also lower in Group B (15.49 ± 2.94) compared to Group A (20.45 ± 2.99, $p<0.001$), indicating less disability. At the 12–16th week follow-up, the difference persisted. Group B achieved near-normal elbow function with MEPS of 91.2 ± 3.9 compared to 85.7 ± 4.3 in Group A ($p<0.001$). Similarly, QuickDASH scores were lower in Group B (8.5 ± 1.4) compared to Group A (12.6 ± 1.9, $p<0.001$).

Complication rates were consistently higher in the DCP group. Infections occurred in 8.6% of Group A versus 2.9% of Group B. Malunion was reported in 5.7% of Group A but absent in Group B. Nerve injury occurred in one patient (2.9%) in Group A but none in Group B. Other complications, including hardware-related problems and stiffness, were more frequent in Group A(17.1%) compared to

Group B (5.7%). Chi-square testing showed a statistically significant difference in overall complication rates between the groups (p=0.04).

Table I: Demographic and Clinical Characteristics (n=70)

Variable	Group A (DCP)	Group B (IMEN)	Total (n=70)	*p*-value
Age (years, mean ± SD)	14.2 ± 2.1	13.8 ± 1.9	14.0 ± 2.0	0.42 (t-test)
Gender (Male/Female)	22 / 13	23 / 12	45 / 25	0.80 (Chi^2)
Affected Limb (Right/Left)	21 / 14	19 / 16	40 / 30	0.62 (Chi^2)

Table II: Primary Outcomes: Healing and Functional Recovery

Outcome Measure	*Group A (DCP)*	*Group B (IMEN)*	*p-value (test)*
Time to Union (weeks)	12.5 ± 2.3	10.8 ± 1.9	0.004 (t-test)
Functional Recovery (weeks)	14.3 ± 2.8	12.1 ± 2.4	0.003 (t-test)
MEPS – 6th Week	75.3 ± 5.2	81.6 ± 4.8	<0.001 (t-test)
MEPS – 12–16th Week	85.7 ± 4.3	91.2 ± 3.9	<0.001 (t-test)
Quick DASH – 6th Week	20.45 ± 2.99	15.49 ± 2.94	<0.001 (t-test)
Quick DASH – 12–16th Week	12.6 ± 1.9	8.5 ± 1.4	<0.001 (t-test)

Table III: Comparison of complication Rates in both groups

Complication	*Group A (DCP)*	*Group B (IMEN)*	*p-value*
Infection	3 (8.6%)	1 (2.9%)	0.04
Malunion	2 (5.7%)	0 (0%)	0.02
Nerve Injury	1 (2.9%)	0 (0%)	0.31
Bleeding	2 (5.7%)	1 (2.9%)	0.55
Other (stiffness, hardware issues)	6 (17.1%)	2 (5.7%)	0.03

DISCUSSION

Though excellent results can be seen in cast treatment, older children and adolescents with both bone forearm fractures totally displaced, usually undergo surgery.[11] The most commonly used two surgery procedures are the open reduction with dynamic compression plating (DCP) and open reduction with intramedullary elastic nailing (IMEN).[12] The DCP continues to be popular with many orthopedic surgeons despite the introduction of more recent plate osteosynthesis techniques as locking plates and restricted contact plates.[13]

Due to minimally invasive in nature, potential of early mobilization, and positive postoperative functional outcomes, intramedullary elastic nailing (IMEN) remains the most used primary surgery method to treat diaphyseal forearm fractures.[14] The use of IMEN, however, is associated with a number of side effects, including wound infection, skin perforation, bursitis, nonunion, tendon rupture, and compartment syndrome. Some studies have shown different rate of complication, ranging between 10 and 67 percent.[15]

Our study revealed that adolescent patients treated with intramedullary elastic nailing (IMEN; Group B) had significantly faster radiographic union (mean 10.8 ± 1.9 weeks) compared to those treated with dynamic compression plating (DCP; Group A; 12.5 ± 2.3 weeks; p = 0.004). Functional recovery, measured via forearm pronation/supination, was also notably quicker in the IMEN group (12.1 ± 2.4 weeks vs. 14.3 ± 2.8 weeks; p = 0.003). Objective scores reinforced this: Group B had significantly higher MEPS and lower QuickDASH scores at both 6-week and 12–16-week follow-ups (all p < 0.001).

In a prospective trial of IMEN treatment, 22 children aged 6-14 years who received treatment reported uneventful recovery at an average of 7.37 weeks, and 86.3 per cent of this group attained excellent and 13.7 per cent good outcomes. Minor side effects were noted including pin tract infection among 4.5% cases and nail protrusion/pain among 9% cases.[16] Our findings in adolescents also highlight the advantages of IMEN compared to plating; it unites significantly faster (10.8 vs. 12.5 weeks, p = 0.004), has a faster functional recovery, and fewer complications, which is also effective in all older age groups. The research substantiates the use of IMEN as an alternative to casting among older children.

According to a recent prospective study, IMEN and locking compression plates (LCP) were compared in people with unstable distal ulnar fractures (n=54). IMEN was associated with unique perioperative advantages, including reduced surgical time, reduced incision dimension, reduced fluoroscopy utilization, and greater rates of excellent/good functional results as assessed by GartlandWerley scores (p < 0.05), despite comparable union time and immobilization between groups (p > 0.05). In our study, it was discovered that intramedullary elastic nailing, rather than plating, resulted in a faster union with an earlier functional recovery at a reduced morbidity and complication rate during operation. This also backs up IMEN as a less invasive and more successful type of fixing.[17]

Most importantly, the IMEN group had a lower incidence of malunions, infection, nerve injuries, and hardware-related problems which were constantly decreasing in number (overall complications p = 0.04). A multicenter study of patients matching age reported that IMEN patients required approximately one half of the length to plate plus that over 70 percent were treated with closed reduction, again in line with our results. Whereas plating was linked to increased occurrence of postoperative neurological complaints, refractures, however, the differences were not statistically significant and both groups had excellent outcomes, with more

than 90 percent achieving acceptable outcomes.[18] Likewise, a meta-analysis of 13 trials of intramedullary nailing vs. ORIF found nailing to reduce surgical time significantly and complication rate significantly. The combined results suggest that both methods are effective, but nailing has perioperative advantages. Our result also reinforced that intramedullary elastic nailing reduced complications relative to plates, which supported these findings ($p = 0.04$).[19]

However, our results contradict those of a former meta-analysis of 16 articles that had shown no apparent difference in unions or functions between intramedullary elastic nailing (IMEN) and plate fixations (PF). On the contrary, as compared to dynamic compression plating, our study established that there were lower complication rates, faster radiographic fusion, and faster functional restoration in adolescents treated with IMEN, despite the fact that that review study reported more hardware-related complication with PF.[12]

In the same manner, a retrospective controlled study of 76 teenagers (mean age 12.5 years; 46 in intramedullary nailing, 30 in plating treatment) there was no significant difference in complications, radial bow restoration, forearm rotation, or union time (7.86 vs. 7.33 weeks, $p = 0.78$) and thus, intramedullary nailing and plated procedures were not found to be different significantly.[20] Nevertheless we found that intra medullary elastic nailing was better than plating in this age group as it resulted in a much faster union period, faster functional recovery and reduced risk of problems. This may be due to our sole focus on AO22 A simple diaphyseal fractures that are more prone to intramedullary treatment than complicated types of fractures.

In another study of 56 adolescents (12-19 years old), comparing dynamic compression plating and intramedullary nailing, there was no significant difference between the two with regard to functional outcomes.[21] In another prospective study, IMEN operated shorter, (55 vs. 90 minutes, $p < 0.001$), and they also fluoroscended longer (59.5 vs. 3 seconds, $p < 0.001$) and had greater rates of superficial infection (20% vs. 0% $p = 0.05$). On the whole, the two approaches were considered to be equally successful.[22]

On the whole, our findings suggest that intramedullary elastic nailing may be the optimal method of fixing uncomplicated diaphyseal fractures of the forearm in adolescents, particularly when a faster recovery to functionality and reduced morbidity are of primary importance. Complicated or comminuted fracture patterns can still need plate fixation to achieve optimal stability, and the selection of the patient is essential.

Despite the merits of this study, a number of limitations should be mentioned. To begin with, the results cannot be generalized to bigger groups of people since the sample is extremely small. Second, long-term follow-up beyond 16 weeks has not occurred, making it harder to evaluate outcomes that particularly matter in adolescents, including refracture, growth abnormalities, or implant migration. Finally, there is no randomization, which increases the risk of selection bias that could have influenced the allocation of treatments and their outcomes. These findings need to be confirmed by future multicenter randomized controlled trials with larger cohorts and extended follow-up, and be considered when interpreting the results.

CONCLUSION

In conclusion, in this study, IMEN was found to exhibit stronger outcomes in comparison to DCP when treating adolescent forearm diaphyseal fractures. The advantages of IMEN make it a popular type of treatment in most cases, since the therapy has several positive effects such as faster recovery of the union, better functional recovery, and fewer issues. DCP is nonetheless useful in the treatment of certain fracture patterns, which require precise alignment with the anatomy. The findings underscore the importance of individualized treatment planning to reach optimal outcomes with this population.

Ethical Approval: Ethical approval was taken from the King Edward Medical University, Lahore IRB No. 159/RC/KEMU dated: 20-3-2024.

Conflict of interest: None

Financial Disclosure: None

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Authors' Contributions:

AHS & AA: Conceptualization & study design.

AA & BM: Data Collection and manuscript drafting.

AH: Data Analysis and critical review.

FM: Supervision &Manuscript drafting & proof reading.

All authors have read and approved the final version of the manuscript and are responsible and accountable for the accuracy and integrity of the work.

1. *Ahmad Humayun Sarfraz*
AP Department of Orthopedic KEMU, Lahore
2. Bilal Mukhtar
MO Department of Orthopedic
KEMU, Lahore
3. Asma Akram
SR Department of Orthopedic
KEMU, Lahore
4. Asad Ali
MO Department of Orthopedic
KEMU, Lahore
5. Asif Hanif
MO Department of Orthopedic
6. Faisal Masood
Professor Department of Orthopedic
KEMU, Lahore