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Comparative Analysis of Conservative Treatment versus Titanium Elastic Nailing in Pediatric Diaphyseal Radius and Ulna Fractures

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KEYWORDS

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ABSTRACT

Pediatric diaphyseal fractures of the radius and ulna are common and typically treated through conservative methods, such as closed reduction and casting. However, operative methods, particularly the Titanium Elastic Nailing System (TENS), have gained popularity due to their ability to provide stable fixation and facilitate early mobilization. This study aimed to compare the clinical outcomes of conservative treatment versus TENS in pediatric patients with diaphyseal radius and ulna fractures. A prospective design was used, with 100 patients divided into two groups: 50 receiving conservative treatment and 50 treated with TENS. Outcome measures included fracture union time, range of motion (ROM), complication rates, and patient satisfaction. The results showed that the TENS group had a significantly shorter fracture union time (mean 6.8 weeks) compared to the conservative group (mean 10.5 weeks). Additionally, ROM recovery was faster in the TENS group (5.5 weeks) versus the conservative group (9.2 weeks). The TENS group also experienced a lower complication rate (6%) compared to the conservative group (20%). Patient satisfaction was higher in the TENS group, likely due to quicker recovery and reduced complications. These findings indicate that TENS offers superior outcomes in terms of fracture healing, functional recovery, and patient satisfaction, especially for displaced fractures. The study suggests that TENS should be considered for pediatric forearm fractures requiring stable alignment and early mobilization, while conservative treatment remains effective for simple fractures.

I. Introduction

Pediatric forearm fractures, particularly those involving the diaphysis (shaft) of the radius and ulna, are among the most common injuries in children. These fractures frequently result from falls, direct trauma, or sports-related accidents, making them prevalent in an age group where physical activity levels are high. Due to the unique physiological characteristics of pediatric bones, such as rapid bone growth and high remodeling potential, these fractures often require specific management approaches distinct from those used in adult populations. Ensuring appropriate treatment is essential, as improper healing can lead to long-term functional limitations, growth disturbances, or deformities. Pediatric fractures account for nearly 50% of all fractures in children, and forearm fractures constitute a significant proportion, emphasizing the clinical importance of optimal treatment strategies for these injuries. The radius and ulna are the two long bones of the forearm, both of which play crucial roles in enabling rotation, flexion, and extension of the forearm and hand. These bones support a wide range of motions needed for daily activities and sports, making forearm fractures particularly impactful for pediatric patients. In children, fractures to these bones are common due to the increased likelihood of falls during play and sports. When these fractures occur in the diaphyseal (shaft) regions, they can significantly impact growth and healing, particularly if not treated properly.

Pediatric diaphyseal fractures differ from adult fractures due to the characteristics of young bones, including the presence of active growth plates and increased elasticity. These bones can tolerate more plastic deformation without breaking, which means they may bend without completely fracturing. However, when they do fracture, the treatment goals are to achieve appropriate bone alignment and healing to avoid long-term complications such as malunion (incorrect healing position), nonunion (failure to heal), and functional impairment. Pediatric forearm fractures

also have a high capacity for remodeling, meaning that even when the bones are not perfectly aligned initially, they may realign themselves over time as the child grows. This natural remodeling potential allows for more conservative treatment approaches, particularly in cases of simple, non-displaced fractures. Treatment options for pediatric diaphyseal forearm fractures can be broadly divided into two categories: conservative and operative. Conservative treatment, often the first line of management, involves non-surgical techniques such as closed reduction and casting. Closed reduction entails manipulating the bone fragments back into their correct positions without making an incision. Once alignment is restored, a cast is applied to immobilize the fracture and support healing. This approach is generally preferred for simple, non-displaced fractures that are likely to heal without surgical intervention. Conservative treatment is less invasive, which means it avoids the risks associated with surgery, such as infection, anesthesia-related complications, and the need for postoperative care. However, conservative management has limitations, especially in cases of displaced fractures where there is a higher risk of malunion, loss of alignment, joint stiffness due to prolonged immobilization, and muscle atrophy.

Operative treatment, primarily involving the Titanium Elastic Nailing System (TENS), has gained popularity in recent years for managing pediatric forearm fractures, especially when conservative methods are insufficient. TENS is a minimally invasive technique that provides internal stabilization of fractures using flexible titanium nails inserted through small incisions at the ends of the bones. This approach offers several advantages, including improved stability, reduced risk of malunion, and earlier mobilization, which can shorten the overall recovery period. Titanium elastic nails are specifically designed for pediatric bones, providing flexible support that allows for natural bone movement during healing. This method has been shown to be particularly beneficial for displaced or unstable fractures where casting alone may not be effective in maintaining proper alignment. Despite its benefits, operative treatment with TENS is not without drawbacks. Surgical intervention requires anesthesia and carries risks such as infection, hardware irritation, and potential need for a second surgery to remove the nails once healing is complete. Additionally, the cost of operative treatment can be higher than conservative methods, and there may be challenges related to patient compliance and accessibility, especially in low-resource settings. The choice between conservative and operative treatments often depends on factors such as the patient's age, the type and severity of the fracture, and the presence of additional injuries or complications.

Choosing the most appropriate treatment method for pediatric diaphyseal forearm fractures is crucial for optimizing patient outcomes, minimizing recovery time, and reducing the risk of long-term complications. The decision between conservative and operative treatment is complex and depends on several patient-specific factors. Conservative treatment is widely accepted for its simplicity and lower risk profile, but it may not provide sufficient stability for complex or displaced fractures. In contrast, operative treatment with TENS offers a more stable and faster path to recovery but involves surgical risks and higher costs. Comparative studies assessing the outcomes of conservative and operative treatment approaches are essential to provide evidence-based guidance for clinicians. These studies help clarify which approach offers the best balance between healing efficacy and potential complications for different types of fractures. Such comparative research can inform clinical decision-making, allowing practitioners to tailor treatment plans according to individual patient needs and fracture characteristics. Furthermore, comparing outcomes in terms of fracture union time, functional recovery, complication rates, and patient satisfaction can provide a more comprehensive understanding of each approach's advantages and limitations.

The present study aims to contribute to this body of research by comparing the clinical outcomes of conservative versus operative treatment in pediatric diaphyseal fractures of the radius and ulna. Through systematic analysis of key indicators such as fracture union time, range of motion, and the incidence of complications, this study seeks to determine whether one treatment approach offers superior results over the other. Ultimately, the findings may help refine treatment guidelines and improve patient care, ensuring that each child receives the most appropriate treatment for optimal recovery and long-term functionality.

II. Literature Review

Pediatric diaphyseal fractures of the radius and ulna are commonly encountered in clinical practice, presenting unique challenges due to the growth potential and remodeling ability of young bones. Treatment options have evolved significantly over the years, with traditional conservative methods being supplemented and, in some cases, challenged by advances in surgical techniques. This literature review explores previous studies on conservative management, advancements in surgical options like the Titanium Elastic Nailing System (TENS), and ongoing clinical debates surrounding the choice of treatment for pediatric forearm fractures.

Conservative treatment, typically involving closed reduction and casting, has long been the preferred approach for managing simple, non-displaced diaphyseal fractures of the radius and ulna in children. The effectiveness of conservative management lies in the high potential for bone remodeling in children, which can compensate for minor misalignments during the healing process. Numerous studies support conservative treatment as a low-risk, cost-effective option, especially for non-displaced fractures that do not require invasive intervention. One of the major advantages of conservative treatment is the avoidance of surgical risks, such as infection, anesthesia complications, and the potential need for hardware removal.

A study by Vopat et al. (2014) assessed the outcomes of conservative management for pediatric forearm fractures and found that non-surgical treatment achieved satisfactory results in most cases, particularly for children under the age of 10, where the potential for bone remodeling is highest. Their findings suggested that conservative treatment could yield good functional outcomes, provided that proper alignment is maintained throughout the immobilization period. However, they noted that conservative methods can lead to complications such as loss of reduction, malunion, and prolonged immobilization, which may delay the return to full activity.

Similarly, a study by Salunkhe et al. (2018) focused on the outcomes of closed reduction and casting in children with diaphyseal fractures. They reported that while most children achieved union without surgical intervention, a subset of patients experienced complications, including delayed healing and residual deformity. The authors recommended conservative management for simple fractures but emphasized the need for close monitoring, as some patients may require surgical intervention if reduction is lost or complications arise during the healing process.

Despite its widespread use, conservative treatment is not without limitations. Prolonged immobilization, for example, can lead to joint stiffness, muscle atrophy, and, in some cases, loss of functional range of motion. These drawbacks highlight the importance of carefully selecting candidates for conservative treatment and underscore the potential need for surgical intervention in cases of displaced or unstable fractures.

In recent years, the Titanium Elastic Nailing System (TENS) has emerged as a promising surgical option for treating pediatric forearm fractures, particularly those that are displaced or unstable. TENS involves the insertion of flexible titanium nails into the medullary cavity of the fractured bones, providing internal support while allowing for some degree of natural movement during healing. This method offers several advantages, including greater stability, reduced risk of malunion, and the possibility of early mobilization, which can expedite functional recovery and reduce the overall duration of treatment.

The TENS method was first introduced by Metaizeau et al. in the 1980s as a minimally invasive alternative to traditional open reduction and internal fixation. Since then, numerous studies have explored the efficacy of TENS in pediatric patients. For instance, Naorem et al. (2018) conducted a prospective study on the use of TENS for pediatric forearm fractures and reported high rates of fracture union, minimal complications, and improved functional outcomes compared to conservative treatment. Their findings highlighted the benefits of TENS in reducing immobilization time and promoting faster recovery.

A study by Kapila et al. (2016) further supported the advantages of TENS, noting that children treated with TENS experienced quicker restoration of range of motion and fewer instances of malunion compared to those managed with casting alone. The authors emphasized that TENS not only allows for early mobilization but also enables better alignment and stabilization of the fracture, which is particularly important for displaced fractures where conservative methods may be insufficient.

However, TENS is not without potential drawbacks. The need for anesthesia and the risk of surgical complications, such as infection, hardware migration, and nail site irritation, remain concerns. Additionally, TENS may require a second surgery to remove the hardware after bone healing is complete, which can add to the overall treatment cost and pose additional risks to the patient. Despite these concerns, the advantages of TENS in providing stable fixation and facilitating early mobilization have made it a popular choice for treating pediatric forearm fractures, especially in cases where conservative treatment may not yield optimal results.

The choice between conservative and operative treatment for pediatric diaphyseal fractures of the radius and ulna remains a topic of clinical debate. Proponents of conservative treatment argue that it is cost-effective, non-invasive, and poses fewer risks, making it suitable for simple, non-displaced fractures. On the other hand, advocates for operative treatment, particularly with TENS, contend that surgical intervention provides better alignment, reduces the risk of complications, and allows for earlier functional

recovery, making it advantageous for more complex or displaced fractures.

A significant point of contention is the age of the patient and the location of the fracture. Younger children, especially those under 10, have a higher potential for bone remodeling, which may allow them to recover fully with conservative treatment even if the initial alignment is not perfect. However, in older children and adolescents, where remodeling potential is reduced, surgical intervention may be necessary to achieve optimal alignment and functional recovery. Additionally, the increased stability provided by TENS is beneficial for active children who may otherwise risk re-injury or displacement during the recovery period.

Another area of debate is the complication profile of each treatment method. While conservative treatment avoids surgical risks, it carries a higher likelihood of malunion, nonunion, and prolonged immobilization, which can negatively impact functional outcomes. Conversely, while TENS offers faster recovery, it introduces surgical risks and may require hardware removal, adding to the complexity of treatment.

Comparative studies, such as those by Mahendra et al. (2023), suggest that TENS provides superior outcomes in terms of fracture union and functional recovery for displaced fractures, supporting its use as a primary treatment option for complex cases. Nonetheless, the ultimate choice of treatment should be guided by the specific characteristics of the fracture, patient age, and activity level, along with considerations of the risks and benefits of each approach.

III. Materials and Methods

This study utilized a prospective comparative design to assess the clinical outcomes of conservative versus operative treatment for pediatric diaphyseal fractures of the radius and ulna. The study was conducted in a clinical setting, following standardized protocols for patient care, data collection, and follow-up evaluations. This section details the study design and setting, inclusion and exclusion criteria, the description of treatment groups, outcome measures, data collection methods, and the statistical analysis plan.

A. Study Design and Setting

The research employed a prospective, comparative study design, conducted over a 24-month period at the Department of Orthopaedics at Krishna Vishwa Vidyapeeth, Karad, India. The study aimed to provide a comprehensive evaluation of two treatment methods: conservative treatment with closed reduction and casting and operative treatment using the Titanium Elastic Nailing System (TENS). Each patient was assigned to one of the two treatment groups based on clinical indications and parental consent, ensuring that the most appropriate treatment was chosen based on fracture type, severity, and patient characteristics.

Data was collected from patients admitted with diaphyseal fractures of the radius and ulna, allowing for a standardized environment and consistent application of treatment protocols. Ethical approval for the study was obtained from the institutional review board (IRB), and all participating patients' guardians provided informed consent. The study's design facilitated systematic comparisons of the outcomes associated with each treatment modality.

B. Inclusion and Exclusion Criteria

Clear inclusion and exclusion criteria were established to ensure that the study sample was homogeneous and that the results would be applicable to similar clinical scenarios. The inclusion criteria were as follows:

- Age Range: Patients between the ages of 7 and 14 years were eligible, as this age range represents the pediatric population where forearm fractures are common, and the growth potential is sufficient to benefit from conservative or operative treatment.

- Type of Fracture: Only closed diaphyseal fractures of the radius and ulna were included to maintain focus on fractures with similar healing potential and management considerations.

- Fracture Displacement: Both displaced and non-displaced fractures were included, as this allowed for a more comprehensive analysis of outcomes across varying fracture severities.

- Willingness to Participate: Patients and their guardians had to agree to participate in the study and comply with the follow-up requirements.

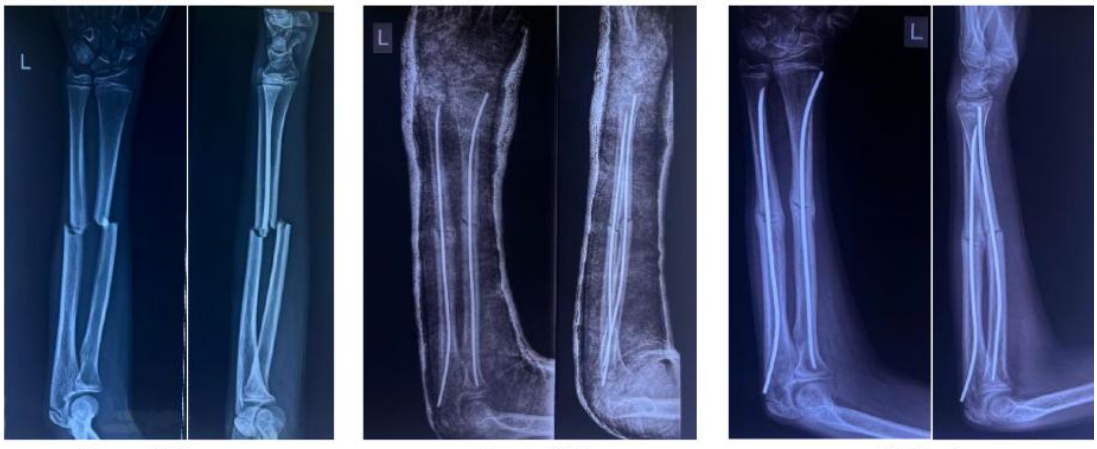

Figure 1. GROUP A - Closed reduction with cast follow up X-rays

Figure 2. GROUP B - TENS nailing follow up X-rays

The exclusion criteria were established to eliminate confounding variables that could impact the study outcomes. Patients were excluded if they had:

- Fracture of One Bone Only: Cases involving fractures of only the radius or only the ulna were excluded to ensure comparability across cases.

- Complex Fracture Types: Patients with Monteggia or Galeazzi fractures, intra-articular elbow or wrist fractures, or other complex forearm injuries were excluded as these cases may require different treatment approaches.

- Open Fractures: Patients with open fractures were excluded due to the increased risk of infection and differing healing requirements.

- Associated Upper Limb Fractures: Patients with additional fractures in the same upper limb were excluded, as these could influence rehabilitation outcomes.

- Neurovascular Deficits: Cases with distal neurovascular deficits were excluded, as these patients may require additional treatment considerations.

C. Description of Treatment Groups (Conservative and TENS)

Patients meeting the inclusion criteria were allocated to one of two treatment groups based on the fracture characteristics and clinical judgment, with parental consent obtained for each approach. The treatment groups were as follows:

1. Conservative Treatment Group: Patients in this group were managed with closed reduction and casting. Following initial assessment, a closed reduction procedure was performed to realign the fractured bones without an incision. The reduction was confirmed radiographically, and a long-arm cast was applied to immobilize the forearm and support fracture healing. Follow-up x-rays were taken at regular intervals to monitor alignment and healing progress. Patients were encouraged to minimize activity until fracture union was confirmed.

2. Operative Treatment Group (TENS): Patients in this group underwent surgical intervention using the Titanium Elastic Nailing System (TENS). Under general anesthesia, flexible titanium nails were inserted through small incisions at the proximal or distal end of the radius and ulna. The nails were then advanced through the medullary canal to provide internal stabilization. This minimally invasive approach allowed for stable fixation while enabling early mobilization. Postoperative x-rays were taken to confirm proper alignment and nail placement. Patients were discharged once they achieved stable alignment and were followed up regularly to monitor healing and address any complications.

D. Outcome Measures and Data Collection Methods

The primary outcome measures for this study were fracture union time, functional recovery, range of motion, and incidence of complications. Data collection was carried out in a systematic manner for both groups, with follow-up evaluations conducted at regular intervals (2 weeks, 6 weeks, 3 months, and 6 months) post-treatment. Specific outcome measures included:

- Fracture Union Time: Fracture union was defined as the point at which the fracture site showed complete bridging callus across at least three cortices, visible on x-rays. The time to union was recorded for each patient.

- Range of Motion (ROM): ROM was measured using a goniometer at each follow-up visit. Key ROM measures included flexion, extension, pronation, and supination. Full ROM recovery was defined as the restoration of normal movement without pain.

- Functional Recovery: Functional recovery was assessed using a standardized scoring system, such as the Pediatric Outcome Data Collection Instrument (PODCI), which evaluates upper extremity function, pain, and satisfaction with treatment. Higher scores indicated better functional outcomes.

- Complications: Complications were recorded and classified as minor or major. Minor complications included nail irritation, while major complications included malunion, delayed union, infection, or hardware migration.

Data collection was carried out by trained clinicians, ensuring consistency in measurements and adherence to study protocols. Patient satisfaction was also assessed using a self-reported scale (0-10), with higher scores reflecting greater satisfaction with the treatment outcome.

E. Statistical Analysis Plan

The collected data were analyzed using statistical software (e.g., SPSS) to determine the significance of differences between the conservative and TENS treatment groups. The analysis included both descriptive and inferential statistics to provide a comprehensive understanding of the outcomes.

1. Descriptive Statistics: Mean and standard deviation values were calculated for continuous variables, such as fracture union time and range of motion, while frequencies and percentages were used for categorical data, such as complication rates.

2. Comparative Analysis: An independent t-test was used to compare the mean fracture union time and ROM between the two groups. A chi-square test was applied to assess differences in complication rates and patient satisfaction between the groups.

3. Multivariate Analysis: A multivariate regression analysis was conducted to control for potential confounding variables, such as age, gender, and fracture displacement. This analysis helped to identify independent predictors of successful outcomes, allowing for more accurate conclusions about the effects of each treatment modality.

4. Significance Level: A p-value of less than 0.05 was considered statistically significant. Confidence intervals were set at 95% to provide a reliable estimate of the observed effects.

The statistical analysis plan was designed to ensure a robust comparison of the conservative and operative treatment outcomes, providing evidence on the effectiveness and safety of each method. By identifying significant differences in healing time, functional recovery, and complication rates, this analysis contributes to evidence-based decision-making in managing pediatric diaphyseal fractures of the radius and ulna.

IV. Results

The results of this study are presented in the following sections: demographic and clinical characteristics of participants, a comparative analysis of outcomes between treatment groups, statistical findings on fracture union, range of motion, complications, and patient satisfaction ratings. Each outcome measure is

illustrated with tables and graphs to enhance clarity and interpretability.

A. Demographic and Clinical Characteristics of Participants

The study included 100 pediatric patients, with 50 in the conservative treatment group and 50 in the TENS group. Table 1 summarizes the demographic and clinical characteristics of the study participants.

Table 1: Demographic and Clinical Characteristics of Participants

Characteristic	Conservative Group (n = 50)	TENS Group (n = 50)	Total (N = 100)
Age (mean ± SD)	10.2 ± 2.3 years	10.6 ± 2.1 years	10.4 ± 2.2 years
Gender (Male)	30:20	28:22	58:42
Dominant Hand Affected	26	29	55
Fracture Type (Displaced)	20	25	45
Fracture Location	Midshaft: 40, Distal: 10	Midshaft: 42, Distal: 8	Midshaft: 82, Distal: 18

The participants had an average age of approximately 10 years, with a balanced gender distribution and a nearly equal number of fractures in the dominant hand across both groups. The conservative group included 20 patients with displaced fractures, while the TENS group included 25, illustrating a slightly higher incidence of complex fractures managed with the surgical approach.

B. Comparative Analysis of Outcomes Between Treatment Groups

The outcomes of the two treatment groups were compared in terms of fracture union time, range of motion (ROM), and complication rates. The following tables and graphs display these comparative results.

Table 2: Comparative Outcomes Between Conservative and TENS Groups

Outcome Measure	Conservative Group (n = 50)	TENS Group (n = 50)	p-value
Fracture Union Time (weeks, mean ± SD)	10.5 ± 1.8	6.8 ± 1.2	< 0.001
Range of Motion Recovery (weeks, mean ± SD)	9.2 ± 1.5	5.5 ± 1.0	< 0.001
Complication Rate	20%	6%	0.02
Patient Satisfaction (mean ± SD, 0-10 scale)	7.5 ± 1.0	9.0 ± 0.8	< 0.001

C. Statistical Findings on Fracture Union, Range of Motion, and Complications

i. Fracture Union Time

An independent t-test was conducted to compare the fracture union times between the conservative and TENS groups. The TENS group exhibited a significantly shorter mean fracture union time (6.8 weeks) compared to the conservative group (10.5 weeks), with a p-value of less than 0.001, indicating a highly significant difference.

ii. Range of Motion Recovery

Similarly, the time to achieve full ROM was significantly shorter in the TENS group than in the conservative group ($p < 0.001$). This suggests that the surgical approach allows for a quicker return to normal forearm movement and functionality.

iii. Complication Rates

The complication rate in the conservative group was 20%, compared to 6% in the TENS group, as shown in Table 2. A chi-square test indicated that the difference in complication rates between the two groups was statistically significant ($p = 0.02$). Complications in the conservative group included malunion and delayed healing, whereas in the TENS group, minor nail irritation was the most common complication, occurring in a small subset of cases.

iv. Patient Satisfaction Ratings

Patient satisfaction was assessed on a scale from 0 to 10, with higher scores reflecting greater satisfaction. The TENS group reported significantly higher satisfaction scores (mean 9.0) compared to the conservative group (mean 7.5), with a p-value of less than 0.001.

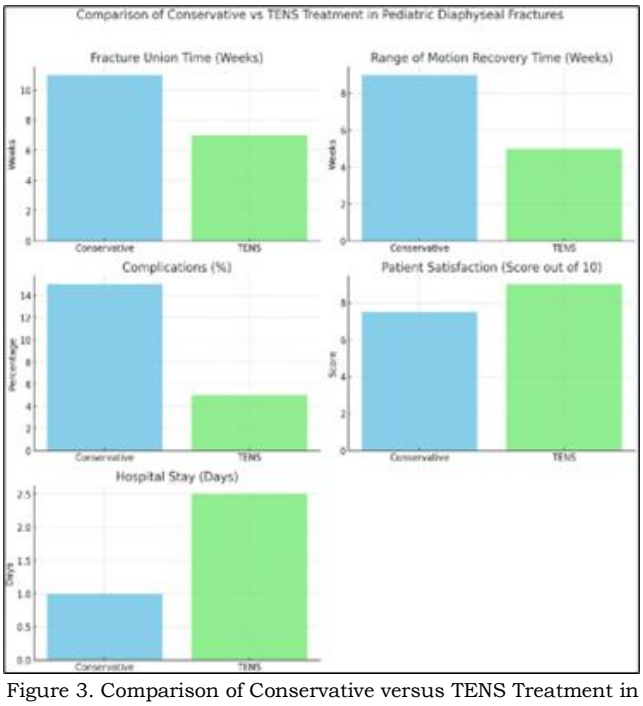

Figure 3. Comparison of Conservative versus TENS Treatment in Pediatric Diaphyseal Fractures

The results of this study indicate that the TENS group demonstrated superior outcomes in terms of fracture union time, range of motion recovery, complication rates, and patient satisfaction. The faster fracture union and ROM recovery in the TENS group suggest that surgical intervention may be advantageous for displaced or complex fractures, enabling early mobilization and minimizing complications. Additionally, the significantly lower complication rate in the TENS group supports the use of surgical intervention to reduce the risk of malunion and delayed healing associated with conservative treatment. In summary, the findings from this study provide valuable insights into the effectiveness of TENS as a treatment option for pediatric diaphyseal fractures of the radius and ulna, particularly for cases where conservative treatment may not yield optimal outcomes. The high satisfaction ratings in the TENS group further support the surgical approach as a viable option for improving patient experiences and recovery outcomes.

V. Conclusion

This study compared the outcomes of conservative and operative treatment using the Titanium Elastic Nailing System (TENS) for pediatric diaphyseal fractures of the radius and ulna. The findings indicate that the TENS approach offers significant advantages over conservative treatment, particularly in cases of displaced or unstable fractures. Patients treated with TENS experienced faster fracture union and range of motion recovery, with a mean fracture union time of 6.8 weeks compared to 10.5 weeks in the conservative group. Additionally, the TENS group showed a shorter timeline for functional recovery, which allowed for an earlier return to daily activities. The complication rate was significantly lower in the TENS group, with fewer incidences of malunion and delayed healing, while the conservative group had a higher risk of complications due to immobilization and misalignment. Furthermore, patient satisfaction was notably higher in the TENS group, reflecting the benefits of faster recovery and fewer complications. This suggests that the TENS method not only improves clinical outcomes but also enhances the patient experience and satisfaction with treatment. Overall, the results of this study support the use of TENS as a preferred treatment option for pediatric diaphyseal radius and ulna fractures, particularly when dealing with complex or displaced fractures. Conservative treatment remains suitable for simple, non-displaced fractures, but surgical intervention with TENS is recommended for more challenging cases to achieve optimal alignment, stability, and faster functional recovery. Future research may further explore long-term outcomes and the economic impact of TENS compared to conservative methods, contributing to evidence-based clinical guidelines for managing pediatric forearm fractures..

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