

General

Comparing the Outcomes of Titanium and Stainless Steel Flexible Nails in Repairing Pediatric Long Bone Fractures

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Background

Traditionally, pediatric femoral fracture treatment favored conservative methods, relying on casting and the inherent bone remodeling ability in immature bones. Surgical intervention was deferred until age 6, as nonoperative approaches often resulted in complications. Titanium elastic nailing (TENS) emerged as an effective treatment for diaphyseal femoral fractures in ages 6 to 16. However, the choice between TENS and stainless steel elastic nailing (SENS) remains debated due to inconsistent findings.

Objective

This study aimed to evaluate the effectiveness of both nailing systems in pediatric long bone fractures.

Methods

A retrospective chart review at William Beaumont Hospital Royal Oak included 83 patients aged 6 to 16 treated with TENS or SENS between January 2011 and January 2021. Data collected encompassed nail related issues, time to fracture union, full weight bearing, and nail removal.

Results

In the TENS group (n=29), the average age was 8.8 ± 2.4 years, and the average BMI was 17.2 ± 3.4 . The SENS group (n=54) had an average age of 9.3 ± 2.7 and an average BMI of 19.7 ± 8.4 . Time to fracture union for TENS was 93.8 ± 60.5 days, while SENS was 82.2 ± 40.0 days.

Conclusion

This study found no statistically significant differences in nail-related complications, time to fracture union, full weight bearing, or nail removal between TENS and SENS in pediatric long bone fractures. The choice between these systems should be based on individual circumstances. Limitations include a small sample size and the study's retrospective nature.

INTRODUCTION

Originally, treatment of pediatric femoral fractures took a conservative approach, relying on casting and the remarkable remodeling ability of more immature bones.¹ Surgical approaches were avoided unless the patient exceeded the age of 6, after which non operative approaches to treatment, such as casting, often resulted in more instances of malunion and other major and minor complications.² Studies have since shown that titanium elastic nailing is an effective treatment of diaphyseal femoral fractures in pediatric patients that range from the ages of 6 to 16.²

Since the use of nailing systems to treat pediatric femoral fractures has become common practice, physicians have pondered whether a titanium elastic nailing system (TENS) or a stainless steel elastic nailing system (SENS) is more appropriate for the fixation of pediatric femoral fractures. Wall et al found that the titanium elastic nailing system's malunion rate was four times higher than that of the stainless steel elastic nailing system.³ Mahar et al found that titanium nails had a greater axial compression stiffness than stainless steel nails.⁴ Other studies found that there was no significant difference in the bone healing, fracture mechanical stability, or complication rate between TENSs and SENSs.^{5,6} The data has proven inconsistent and

more studies need to be conducted to properly evaluate which nail system is more appropriate for a pediatric patient population.⁷ A systematic review done by Mohamed et al found that SSENS is the overall cheaper option when compared to TENS and that more potent evidence is required to assess the effectiveness of both nailing systems.⁷ This study looks to assess the effectiveness of both TENS and SSENS not only in pediatric femoral fractures but in pediatric long bone fractures in general.

MATERIALS AND METHODS

This project was a single center retrospective chart review done at William Beaumont Hospital Royal Oak. This study was conducted using 83 patients who were admitted to William Beaumont Hospital Royal Oak between the dates of January 2011 and January 2021. We included patients between the ages of 6 and 16 who had used either titanium or stainless steel nailing systems for the treatment of long bone fractures. Rate of nail irritation requiring revision surgery, rate of nail irritation, rod breakage, superficial infection, time to fracture union, time to full weight bearing, and time to nail removal were all collected by reviewing patient charts. Time to fracture union was measured as the number of days between the date of the fracture and the first X-ray that showed a healed fracture. Time to full weight bearing was calculated as the number of days between the date of the fracture and the first charted note that stated that the patient is able to bear their full weight.

Exclusion criteria included pediatric patients who had long bone fractures treated through methods other than titanium elastic nailing systems or stainless steel elastic nailing systems and patients outside the ages of 6 to 16 years old.

STATEMENT OF ETHICS

Human subjects: Consent was obtained or waived by all participants in this study. Beaumont Research Institute issued approval 2022-187. The Institutional Review Board has reviewed the above referenced research proposal and documents (if applicable) which were submitted for exemption consideration. A Research Waiver of Authorization is granted only for the stipulation of identification/data collection of the specific data variables for this study. The IRB determined: Action: Acceptance of Exemption Category: Category 4: Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met: iii. The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E [HIPAA], for 3 of 4 the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b). Acceptance Date: December 21, 2022 IRB has acknowledged the following documents: - OUWB Capstone/Embark Pro-

ject - OUWB Medical Student Capstone Research Assurance Form - Protocol, embark proposal (version date 11/09/2022) -Data Collection Tool, list of variables (version date 11/09/2022) - Approved number of participants/charts to be enrolled: Up to 5000 - Age range of participants: 6 to 16 years of age - Date range for data collection: 01/2011 – 01/2021 - Initial IRB Study Application version: 1.2 - The inclusion of the targeted Vulnerable Participant Population of Children (< 18 years of age) and the possible incidental inclusion of the following Vulnerable Participant Population(s) has been determined appropriate: o Pregnant Women, Fetuses & Neonates o Economically or Educationally Disadvantaged Individuals o Students/Trainees/Staff o Decisionally Impaired or Mentally Disabled Individuals. Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

RESULTS

In the TENS group there were a total of 29 patients. In the SSENS group there were a total of 54 patients. The average age in the TENS group was 8.8+/-2.4 ranging from 6 to 14 years old. The average age in the SSENS group was 9.3+/-2.7 ranging from 6 to 16 years old. The average Body-Mass-Index(BMI) in the TENS group was 17.2+/-3.4 ranging from 13 to 25. The average BMI in the SSENS group was 19.7+/-8.4 ranging from 11 to 71. There was no statistically significant difference in the rate of nail irritation not requiring revision surgery between the two groups. There was no statistically significant difference in the rate of nail irritation requiring revision surgery between the two groups. There were no incidents of rod breakage in either of the two groups. Superficial infection was found in (0)1 patient in the TENS group and 0 patients in the SSENS

group. The time to fracture union for the TENS group was 93.8+/-60.5 days on average with a range of 25 days to 254 days. The time to fracture union for the SSENS group was 82.2+/- 40.0 days on average with a range of 16 days to 181 days. Time to full weight bearing for the TENS group was 66.9+/-38.0 days on average with a range of 25 to 161 days. The time to full weight bearing for the SSENS group was 80.0+/-46.7 days on average with a range of 16 to 213 days. The time to nail removal for the TENS group was 200.6 +/- 102 days on average with a range of 117 days to 651 days. The time to nail removal for the SSENS group was 187.3 +/- 70.6 days on average with a range of 64 days to 413 days.

DISCUSSION

The key finding of this study is the absence of statistically significant differences in various clinical outcomes between the TENS and SSENS groups. Specifically, there were no significant disparities in the rates of nail irritation requiring revision surgery, rates of nail irritation, rod breakage, or superficial infection. While the study did identify differences in the time to fracture union and time to full weight bearing, these differences did not reach statistical significance.

These results may be somewhat surprising given the existing body of literature, which has reported mixed findings on the comparative effectiveness of these nailing systems. Wall et al. reported a higher malunion rate with TENS compared to SSENS, while Mahar et al. found differences in axial compression stiffness between titanium and stainless steel nails. However, other studies have failed to find significant differences in bone healing, mechanical stability, or complication rates between the two systems. The inconclusive nature of prior research highlights the need for further investigation, as acknowledged in the introduction.

One notable aspect of this comparison is the cost-effectiveness of the two nailing systems. The systematic review by Mohamed et al. identified SSENS as the more cost-effective option. Given the lack of statistically significant differences in clinical outcomes, cost considerations may play a substantial role in guiding treatment decisions. The cost-effectiveness of SSENS may make it an attractive choice for healthcare facilities aiming to optimize resource allocation.

There are several limitations of this study. The relatively small sample size and the single-center, retrospective design are inherent limitations that may restrict the generalizability of our findings.

Additionally, the study compared outcomes of TENS and SSENS in different pediatric long bones without controlling for specific bone locations, potentially introducing confounding variables.

CONCLUSIONS

There was no statistically significant difference between the rate of nail irritation requiring revision surgery, rate of nail irritation, rod breakage, superficial infection, time to fracture union, time to full weight bearing, and time to nail removal of the two groups. Based on these results, no conclusive evidence was found that one nailing system is superior to the other in terms of clinical outcomes. For this reason, selecting a particular nailing system is dependent on individual circumstance. While TENS have been the more popular choice, SSENS have been the more cost effective option of the two. The limitations of this study include the relatively small sample size and the fact that this is a single center retrospective study. Another limitation is that this study compared outcomes of TENS and SSENS in different pediatric long bones. Ideally in future studies there would be a larger sample size comparing clinical outcomes of the two nailing systems in the treatment of specific long bones.

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AUTHOR CONTRIBUTIONS

N.B., S.K. and E.S. conceived of the presented idea. N.B. developed the theory and performed the computations. M.Z. and A.A. verified the analytical methods and analyzed the presented results of the data. E.S. and S.K. encouraged N.B., A.A., and M.Z. to investigate the outcomes and long-term impacts and differences of both variables in addition to su-

pervising the findings of this work. All authors discussed the results and contributed to the final manuscript.

AUTHOR DISCLOSURES

In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: N/A declare(s) Consulting from Stryker. Dr. Fischgrund, the Department Chief of Orthopedic Surgery at Beaumont Hospital Royal Oak, has received payment from Stryker Corporation for consulting work performed. Stryker is a manufacturer of devices that could have been used as part of the surgical procedure being investigated in this study. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Characteristic	Titanium Elastic Nailing System	Stainless Steel Elastic Nailing System	P-Value
Age (years)	8.8 (2.4)	9.3 (2.7)	0.3449
BMI (kg/m ²)	17.2 (3.4)	19.7(8.4)	0.1636
Time to Fracture Union (days)	93.8 (60.5)	82.2 (40.0)	0.3832
Time to Full Weight Bearing (days)	66.9 (38.0)	80.0 (46.7)	0.2846
Time to Nail Removal (days)	200.6 (102.0)	187.3 (70.1)	0.4893

Table 1. Comparison of Patient Characteristics and Clinical Timelines Between TENS and SSENS

A comparison of patient characteristics and clinical timelines between those treated with Titanium Elastic Nailing System (TENS) and Stainless Steel Elastic Nailing System (SENS). For age and BMI, we present the means with standard deviations, while for time intervals, we show the mean durations with standard deviations. The third column displays P-values based on equal variance two sample t-tests.

Characteristic	Titanium Elastic Nailing System	Stainless Steel Elastic Nailing System	P-Value
Nail irritation requiring revision surgery (%)	3.7	2.2	1.000
Nail irritation - no revision (%)	7.4	6.5	1.000
Superficial Infection (%)	3.7	0.0	0.3699

Table 2. Comparison of Complication Rates Between TENS and SSENS

A comparison of complication rates between patients treated with Titanium Elastic Nailing System (TENS) and Stainless Steel Elastic Nailing System (SENS). The table includes the rates of various complications such as nail irritation (with and without revision surgery), and superficial infection. Fisher exact p-values are provided to assess the statistical significance of differences between the two treatment groups for each complication. p-values less than 0.05 indicates statistically significant differences.

REFERENCES

1. McKibbin B. The biology of fracture healing in long bones. *J Bone Joint Surg Br.* 1978;60-B(2):150-162. doi:[10.1302/0301-620X.60B2.350882](https://doi.org/10.1302/0301-620X.60B2.350882)
2. Saikia K, Bhuyan S, Bhattacharya T, Saikia S. Titanium elastic nailing in femoral diaphyseal fractures of children in 6-16 years of age. *Indian J Orthop.* 2007;41(4):381-385. doi:[10.4103/0019-5413.33876](https://doi.org/10.4103/0019-5413.33876)
3. Wall EJ, Jain V, Vora V, Mehlman CT, Crawford AH. Complications of titanium and stainless steel elastic nail fixation of pediatric femoral fractures. *J Bone Joint Surg Am.* 2008;90(6):1305-1313. doi:[10.2106/JBJS.G.00328](https://doi.org/10.2106/JBJS.G.00328)
4. Mahar AT, Lee SS, Lalonde FD, Impelluso T, Newton PO. Biomechanical comparison of stainless steel and titanium nails for fixation of simulated femoral fractures. *J Pediatr Orthop.* 2004;24(6):638-641. doi:[10.1097/00004694-200411000-00008](https://doi.org/10.1097/00004694-200411000-00008)
5. Gyaneshwar T, Nitesh R, Sagar T, Pranav K, Rustagi N. Treatment of pediatric femoral shaft fractures by stainless steel and titanium elastic nail system: A randomized comparative trial. *Chin J Traumatol.* 2016;19(4):213-216. doi:[10.1016/j.citee.2016.02.001](https://doi.org/10.1016/j.citee.2016.02.001)
6. Marengo L, Nasto LA, Michelis MB, Boero S. Elastic stable intramedullary nailing (ESIN) in paediatric femur and tibia shaft fractures: Comparison between titanium and stainless steel nails. *Injury.* 2018;49 Suppl 3:S8-S11. doi:[10.1016/j.injury.2018.09.049](https://doi.org/10.1016/j.injury.2018.09.049)
7. Mohamed A, Rajeev AS. Clinical outcomes and complications of titanium versus stainless steel elastic nail in management of paediatric femoral fractures-a systematic review. *Eur J Orthop Surg Traumatol.* 2017;27(2):157-167. doi:[10.1007/s00590-016-1880-x](https://doi.org/10.1007/s00590-016-1880-x)