



Research

Is Submuscular Plating as Effective and Safe as Elastic Stable Intramedullary Nailing for Pediatric Diaphysial Fractures of the Femur?

Pediyatrik Femur Diyafiz Kırıklarında Submusküler Plaklama, Elastik Çivileme Kadar Etkili ve Güvenli midir?

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ABSTRACT

Objective: The aim of this study was to compare outcomes of submuscular plating (SMP) and elastic stable intramedullary nailing (ESIN) techniques in pediatric diaphysial fractures of the femur. We hypothesize that SMP technique is as safe and effective as ESIN technique for treating diaphysial fractures of the femur.

Methods: Hospital database was searched for surgically treated diaphysial femur fracture patients between January 2018 and January 2022. Patients were separated into two groups. Group A (n=23) consisted of patients treated with SMP technique and Group B (n=26) consisted of patients treated with ESIN technique. Age, gender, injury mechanism, length of hospital stay, union, complications, shortening, operation time and surgical techniques were evaluated. In order to assess post-operative outcomes, criteria described by Flynn were used [9]. In order to evaluate functional outcomes, hip and knee range of motion (ROM) were measured.

Results: Median values of age, gender and injury mechanism distributions as well as mean hospital stay, union ratio, open reduction ratio and mean time of surgery were similar. Time to visible callus and subsequent mobilization was significantly less in group A (3.7 weeks) compared to group B (4.3 weeks). (p<0.001). Clinical, functional and radiological outcomes were statistically similar.

Conclusion: Our study demonstrates that both SMP and ESIN methods provide high rates of union with satisfying clinical, radiological and functional outcomes. SMP is associated with earlier callus formation and patient mobilization. SMP technique may be as safe and as effective as ESIN technique for pediatric diaphysial fractures of femur.

Keywords: Elastic nailing, Femoral fracture, Submuscular plating

ÖZ

Amaç: Pediyatrik femur shaft kırıklarının tedavisinde submusküler plaklama (SMP) ve elastik çivileme (ESIN) tekniklerini karşılaştıran yayınlar azdır. Pediyatrik femur shaft kırıklarının tedavisinde SMP tekniğinin de ESIN tekniği kadar etkili ve güvenilir bir tedavi yöntemi olduğu hipotezini kurduk.

Gereç ve Yöntem: Hastane veritabanı cerrahi olarak tedavi edilmiş pediyatrik femur shaft kırıkları açısından Ocak 2018 ve Ocak 2022 yılları arasında içermek üzere tarandı. Hastalar iki gruba ayrıldı. Grup A (n=23), SMP tekniği ile tedavi edilen hastalardan oluşurken grup B (n=26) ise ESIN tekniği ile tedavi edilen hastalardan oluşmaktaydı. Yaş, cinsiyet, yaralanma mekanizması, hastanede kalış süresi, kaynama, komplikasyonlar, kısalma, ameliyat süresi ve cerrahi teknikler değerlendirildi. Ameliyat sonrası sonuçları değerlendirmek için Flynn tarafından tanımlanan kriterler kullanıldı. Fonksiyonel sonuçları değerlendirmek amacıyla kalça ve diz hareket açıklığı ölçüldü.

Bulgular: Yaş, cinsiyet ve yaralanma mekanizması dağılımlarının median değerleri ile ortalama hastanede kalış süresi, kaynama oranı, açık redüksiyon oranı ve ortalama ameliyat süresi benzerdi. Görünür kallus ve mobilizasyona kadar geçen süre, grup B'ye (4-3 hafta) kıyasla grup A'da (3-7 hafta) anlamlı derecede daha kısaydı. (p<0,001). Klinik, fonksiyonel ve radyolojik sonuçlar istatistiksel olarak benzerdi.

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ÖZ

Sonuç: Çalışmamız, hem SMP hem de ESIN yöntemlerinin tatmin edici klinik, radyolojik ve fonksiyonel sonuçlarla birlikte yüksek oranda kaynama sağladığını göstermektedir. SMP, daha erken kallus oluşumu ve hasta mobilizasyonu ile ilişkilidir. Pediyatrik femur diyafiz kırıklarında SMP tekniği, ESIN tekniği kadar güvenilir ve etkili olabilir.

Anahtar Kelimeler: Elastik çivileme, submusküler plaklama, femur kırığı

INTRODUCTION

Diaphyseal fractures of the femur are among the most common pediatric fractures, representing approximately 2% of all childhood fractures (1). The most common injury mechanisms are falling from a height and motor vehicle accidents (2). These fractures can be unstable and challenging to treat due to strong deforming forces acting on the diaphyseal region of the femur (3).

Several fixation methods have been defined for these fractures (4). Elastic stable intramedullary nailing (ESIN) fixation is the most commonly used treatment method for pediatric femoral shaft fractures (5). On the other hand, submuscular plating (SMP), which is a minimally invasive bridge plating technique, has been a standing out alternative treatment method for these fractures. Various institutions have different treatment choices that may depend on the patient's age and weight (6). However, high-quality evidence is lacking, and the ideal fixation method is highly debated among authors (7). In addition, the literature does not provide adequate information regarding the preference of a particular method among all (8).

Throughout the current literature, very few studies have compared the out-comes of SMP and ESIN. We hypothesized that the SMP technique would be as safe and effective as the ESIN technique for treating diaphyseal fractures of the femur. We aimed to retrospectively compare the radiological, clinical, and functional outcomes of SMP and ESIN.

METHODS

Istanbul Health Sciences University Kanuni Sultan Süleyman Training and Research Hospital permission was obtained (number: 2023.08.98, date: 08.10.2023). Patient-related information was gathered anonymously from the hospital database. In this study, evaluations were performed by neutral orthopedic surgeons who were not the attending surgeons of the patients and did not take any part in any of the procedures.

In this retrospective study, a hospital database was searched for patients with surgically treated diaphyseal femur fracture between January 2018 and January 2022. Radiological data was obtained from Picture Archiving and Communications

System, surgical data was gathered from operational notes, and clinical and functional data were acquired through out-patient clinic notes. Surgical interventions utilizing techniques other than SMP and ESIN were excluded. Fractures were classified according to the AO/OTA classification system. Patients with fractures other than AO/OTA 32A and AO/OTA 32B fractures were excluded. Pathological fractures, segmented fractures, open fractures, polytrauma patients, patients with additional ipsilateral lower extremity fracture, patients without proper follow-up, patients weighing more than 50 kg, and patients older than 18 and younger than 5 years were excluded from the study. The remaining patients were divided into two groups. Group A (n=23) consisted of patients treated with the SMP technique, and Group B (n=26) consisted of patients treated with the ESIN technique.

Data Collection and Evaluation Criteria

Patient information was obtained from the hospital database. The following parameters were evaluated: Age, gender, injury mechanism, length of hospital stay, union, complications, shortened operation time, and surgical technique. In order to assess postoperative outcomes, the criteria described by Flynn were used (9). Radiographic presence of a callus on three of four cortices on anteroposterior and lateral views in addition to absence of pain at the fracture site was defined as a successful union. To evaluate functional outcomes, hip and knee range of motion (ROM) were measured.

Surgical Procedure

Surgery was performed by surgeons with at least 5 years of experience. All surgeries were performed under general anesthesia with preoperative cefazolin administration. Routine preoperative planning was performed in accordance with standard fracture surgical planning techniques (10). The surgical technique utilized was according to the surgeon's preference, due to the variety of experience and training backgrounds. The SMP technique requires closed reduction and proper alignment of the fracture using fluoroscopy. In this technique, 3.5- or 4.5-mm low-contact dynamic compression plates [tuberculin skin test (TST), İstanbul, Türkiye] are used. Relative stability is the goal rather than correct fixation and compression. This technique achieves proper alignment and adequate length-stability. The plate is

placed laterally using adequate-sized mini-incisions distally and proximally without exposing the fracture site. The plate is introduced to the fracture site, where it enters from the distal femur and advances to the proximal femur. The plate should be advanced submuscularly without disrupting the periosteum. At least six cortices must be fixed to the plate at both the proximal and distal sides of the fracture site to begin early mobilization. (Figure 1). The ESIN technique requires titanium elastic nails [titanium elastic nail (TEN), TST, İstanbul, Türkiye]. Two TENs are introduced from stab incisions laterally and medially at the supracondylar region of the distal femur, followed by cortical entry just above the physical line, while closed reduction and proper alignment of the fracture are maintained. Stability is achieved by the expansile acting forces created by the TENs, which contribute to achieving proper alignment while minimizing length stability (Figure 2).

Statistical Analysis

In this study, patients' demographic and clinical data were evaluated by orthopedic surgeons other than the attending surgeons using descriptive statistical analyses (number, percentage, average, standard deviation etc.). The Mann-Whitney U test was used to compare the following parameters between the SMP and ESIN groups: Age, Knee ROM, hip ROM, and qualities of the surgical treatment. Furthermore, the chi-square test was utilized to compare the following parameters between the two groups: Gender, injury mechanism, and outcomes of the surgical intervention. In addition, multivariate binary logistic regression analysis was used to assess the factors affecting treatment success. For all analyses, significance was designated as $p < 0.05$. Compliance with normal distribution was assessed using kurtosis and skewness values ($\pm 1,5$). The IBM SPSS Statistics 26 (IBM, Chicago, IL, USA) software was used for statistical analyses.



Figure 1. Preoperative and postoperative radiographic views of submuscular plating



Figure 2. Preoperative and postoperative radiographic views of elastic stable intramedullary nailing

RESULTS

The initial screening included 462 patients. After applying the inclusion and exclusion criteria, 49 patients were found eligible for the study. The mean age of the included patients was 9 (5-16). Thirty of the patients were male and 19 were female. According to the AO/OTA classification system, 26 patients (53%) had AO/OTA 32A fracture and 23 patients (47%) had an AO/OTA 32B fracture. The mechanism of injury was fall from a height in 34 patients (69%), motor vehicle accident in 10 patients (20%), and other trauma mechanism in 5 patients (11%). Patients were divided into two groups depending on the surgical technique used. According to the Mann-Whitney U test, median age was similar between the two groups ($p=0.384$). According to the chi-square test, gender ($p=0.962$) and injury mechanism ($p=0.765$) distributions were similar between the two groups. (Table 1)

Group A consisted of 23 patients (47%) who underwent surgery using the SMP technique and group B consisted of 26 patients (53%) who underwent surgery using the ESIN technique. 13 patients in group A had an AO/OTA 32A type fracture, whereas 10 patients sustained an AO/OTA 32B type fracture. On the other hand, AO/OTA 32A-type fractures were identified in 14 patients and AO/OTA 32B-type fractures were seen in 12 patients in group B. The mean length of hospital stay was 3.3 days in Group A and 3.4 days in Group B ($p=0.653$). Union was achieved within 12 weeks in all patients in both groups. According to the chi-square test, no significant difference was identified regarding open

reduction, as it was necessary in 6 patients (26%) in group A and in 13 patients (50%) in group B ($p=0.086$). According to the Mann-Whitney U test, no significant difference was identified regarding the mean time of surgery, as it was 73.9 minutes in group A and 88 minutes in group B ($p=0.801$). On the other hand, according to the Mann-Whitney U test, the time to visible callus and subsequent mobilization was significantly shorter in group A (3.7 weeks) than in group B (4.3 weeks). ($p<0.001$). (Table 2)

Postoperative outcomes were evaluated according to the Flynn criteria. These criteria consisted of leg length discrepancy (LLD), angular deformity, pain, and presence of complications. Each criterion was graded as excellent, satisfactory, or poor (8). Regarding LLD, overall excellent results were obtained in 23 patients (100%) in group A and 25 patients (96.2%) in group B ($p=0.342$). Regarding angular deformity, overall excellent results were obtained in 22 patients (95.7%) in group A and 24 patients (92.3%) patients in group B ($p=0.626$). Regarding pain, overall excellent results were obtained in 21 patients (91.3%) in group A and 25 patients (96.2%) in group B ($p=0.558$). Regarding complications, overall excellent results were obtained in 19 patients (82.6%) in group A and 22 patients (84.6%) patients in group B ($p=0.850$). These results did not show a significant difference between the two groups. (Table 3)

In order to thoroughly evaluate postoperative outcomes using the Flynn criteria, treatment results were divided into two groups entitled as "entirely excellent results" and "others". "Others" was defined as having an inferior

Table 1. Comparison of age, sex, and injury mechanism between the SMP and ESIN groups

		SMP		ESIN		p
Age (Med./25-75%)		9.00	7.00-12.00	8.00	7.00-10.00	0.384 ^a
Gender (n/%)	Female	9	39.1	10	38.5	0.962 ^b
	Male	14	60.9	16	61.5	
Injury mechanism (n/%)	FFH	16	69.6	18	69.2	0.765 ^b
	MVA	4	17.4	6	23.1	
	OTHER	3	13.0	2	7.7	

FFH: Fall from height, MVA: Motor vehicle accident, SMP: Submuscular plating, ESIN: Elastic stable intramedullary nailing, Med.: Median, a: Mann-Whitney U test, b: Chi-square test

Table 2. Comparison of the clinical outcomes of surgical techniques

		SMP		ESIN		p
Hospital stay (days) (Med./%25-75)		3.00	3.00-4.00	3.00	3.00-4.00	0.653 ^a
Union (n/%)	Yes	23	100.0	26	100.0	-
	No	17	73.9	13	50.0	
Open reduction (n/%)	Yes	6	26.1	13	50.0	0.086 ^b
	No	17	73.9	13	50.0	
Time of surgery (Med./25-75%)		65.00	60.00-85.00	87.50	50.00-125.00	0.801 ^a
Time to callus and mobilization (weeks) (Med./25-75%)		3.50	3.00-4.00	4.25	4.00-5.00	<0.001 ^a

SMP: Submuscular plating, ESIN: Elastic stable intramedullary nailing, Med.: Median, a: Mann-Whitney U test, b: Chi-square test

Table 3. Comparison between the SMP and ESIN groups according to the outcomes related to the Flynn criteria

		SMP		ESIN		p
		n	%	n	%	
LLD (cm)	Excellent	23	100.0	25	96.2	0.342
	Poor	0	0.0	1	3.8	
Angular deformity (degrees)	Excellent	22	95.7	24	92.3	0.626
	Satisfactory	1	4.3	2	7.7	
Pain	Excellent	21	91.3	25	96.2	0.558
	Poor	1	4.3	1	3.8	
	Satisfactory	1	4.3	0	0.0	
Complication	Excellent	19	82.6	22	84.6	0.850
	Satisfactory	4	17.4	4	15.4	

Chi-square test result.
SMP: Submuscular plating, ESIN: Elastic stable intramedullary nailing, LLD: Leg length discrepancy

Table 4. Evaluation of the parameters affecting treatment success

	B	SE	Wald	df	p	Odds Ratio	95% CI	
							LL	UL
Age	.169	.162	1.083	1	.298	1.184	.862	1.626
Gender (Female)	-.341	.873	.152	1	.696	.711	.129	3.936
Open reduction (No)	-.584	.810	.520	1	.471	.558	.114	2.727
Surgical technique (ESIN)	-.109	.827	.017	1	.895	.897	.177	4.536

R2: 0.06, X2: 1.76, p: 0.780, ESIN: Elastic stabile intramedullary nailing, Multivariate Binary Logistic Regression Analysis, n: 49, Nagekkerke

Table 5. Comparison of knee and hip ROM between the SMP and ESIN groups

	SMP		ESIN		p
	Med.	25-75%	Med.	25-75%	
Knee Rom	135.00	135.00-140.00	135.00	135.00-140.00	0.786
Hip Rom	140.00	135.00-140.00	135.00	135.00-140.00	0.271

Mann-Whitney U test. ROM: Range of motion, SMP: Submuscular plating, ESIN: Elastic stable intramedullary nailing, Med.: Median

clinical status compared to the “entirely excellent result” group, therefore being the less successful group. Next, these two groups were analyzed using multivariate binary logistic regression analysis. According to this analysis, the parameters designated in the model had no significant effect on treatment success ($p > 0.05$). (Table 4)

Functional outcomes were evaluated by examining the knee and hip ROM using the Mann–Whitney U test. The mean range of knee flexion-extension in group A was 136.3, whereas it was 136.5 in group B ($p = 0.786$). The mean range of hip flexion-extension in group A was 138, whereas it was 137.1 in group B ($p = 0.271$) (Table 5).

There were two cases of superficial skin infection in the SMP group and two cases of superficial infection and two cases of skin irritation at the nail entry points in the ESIN group. The superficial skin infections of the SMP patients resolved with antibiotic therapy without the need for additional surgical intervention, whereas the ESIN patients healed

after implant removal. There was a need for prolonged open surgery for two SMP patients who sought implant removal after 1 year of absence because the plate was covered up with overgrown bone tissue.

DISCUSSION

In this study, we identified several outcomes. First, there was no significant difference in the demographic data of the SMP and ESIN groups. Second, clinical evaluation demonstrated no significant difference between the two groups, except for the time to callus and mobilization. Third, no statistically significant difference was identified between the SMP and ESIN groups according to the Flynn criteria (8). Finally, statistically similar results were obtained by evaluating the knee and hip ROM in both groups.

The main concern with both methods is malalignment due to the closed reduction technique. Edwards et al.

(11) concluded that plating diaphyseal fractures of the femur in pediatric populations provides better clinical results compared with the ESIN technique. Abdelgawad et al. (12) also reported less malalignment with the SMP technique. Kanlic et al. (13) demonstrated no symptomatic malalignment in their study with 51 patients and reported excellent union in all fractures treated with the SMP technique. In contrast, Flynn et al. (9) reported excellent outcomes with the ESIN technique regarding alignment (including rotational). In our study, we found no statistically significant difference in alignment between the two groups regarding alignment ($p=0.626$).

Furthermore, various clinical outcomes have been reported in the literature. Regarding operation time, Allen et al. (14) reported a shorter operation time with ESIN. Caglar et al. (15) also reported longer mean operation times for SMP than for ESIN. However, we found statistically similar results when we evaluated the operation times for the two techniques ($p=0.801$). Regarding hospital stay, Wang et al. (16) reported a shorter duration of hospital stay. On the contrary, we found no statistically significant difference between the two groups ($p=0.653$). Regarding union, Reddy et al. (17) demonstrated earlier radiologic union with the ESIN technique. Interestingly, we found statistically similar results of radiologic union between the two groups. The need for open reduction was evaluated by Milligan et al. (18) in a retrospective study including 28 patients, and they found no significant difference between the SMP and ESIN groups. Our study also demonstrated similar results regarding the need for open reduction ($p=0.086$).

In addition, the Flynn criteria (8) were evaluated by most of the studies in the literature. Xu et al. (19) compared 39 patients treated using the ESIN technique with 28 patients treated with plate fixation and demonstrated statistically similar, excellent, and good results for both groups in their study. Sanjay et al. [20] also performed a similar evaluation using the Flynn criteria (8) in their retrospective study involving 40 patients. Our results regarding the Flynn criteria matched with the literature and we came up with statistically similar results ($p=0.342$ for LLD, $p=0.626$ for angular deformity, $p=0.558$ for pain and $p=0.850$ for complication).

Functional outcomes were also evaluated for both groups. Hip and knee ROM were measured in both patient groups by various authors. Xu et al. (19) evaluated hip and knee ROM and found similar results. In our study, all patients in both groups achieved knee and hip ROM within the functional limits. In addition, the results were statistically similar between the two groups ($p=0.786$ for knee ROM and $p=0.271$ for hip ROM).

Complication data for SMP and ESIN techniques were also evaluated by various authors. Xu et al. (19) reported similar rates of complications. Ho et al. (21) showed 22% complication rate of 22% for ESIN. In our study, the cases of superficial skin infection in both groups resolved with antibiotic therapy without the need for additional surgical intervention, whereas the ESIN patients healed after implant removal. We report similar complication rates for both techniques ($p=0.850$).

We believe that we have elaborated on a widely debated topic in the literature. The functional and radiological outcomes of this study may help surgeons select appropriate surgical treatment. The major limitation of this study was its retrospective nature. More objective and significant results can be obtained from randomized controlled prospective studies. Another limitation of this study was the low number of patients due to the rarity of this fracture. The number of patients can be increased by running multiple centered studies.

CONCLUSION

The selection of surgical techniques for the treatment of pediatric diaphyseal fractures is challenging. The results of this study demonstrate that both SMP and ESIN provide high union rates. Both techniques are associated with satisfactory clinical, functional, and radiological outcomes. However, according to the results of our study, SMP was associated with earlier callus formation and patient mobilization. We believe that the SMP technique may be as safe and effective as the ESIN technique for pediatric diaphyseal fractures of the femur.

ETHICS

Ethics Committee Approval: İstanbul Health Sciences University Kanuni Sultan Süleyman Training and Research Hospital permission was obtained (number: 2023.08.98, date:).

Informed Consent: In this retrospective study, a hospital database was searched for patients with surgically treated diaphyseal femur fracture between January 2018 and January 2022.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: G.Ç., C.E., Concept: G.Ç., C.E., Design: G.Ç., C.E., Data Collection or Processing: O.Ç., Y.E., Analysis or Interpretation: O.Ç., Y.E., Literature Search: O.Ç., Y.E., Writing: G.Ç., O.Ç., Y.E., C.E.

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REFERENCES

- Sela Y, Hershkovich O, Sher-Lurie N, Schindler A, Givon U. Pediatric femoral shaft fractures: treatment strategies according to age--13 years of experience in one medical center. *J Orthop Surg Res.* 2013 Jul 17;8:23.
- Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and mechanisms of femur fractures in children. *J Pediatr Orthop.* 2006 Sep-Oct;26(5):561-6.
- Samora WP, Guerriero M, Willis L, Klingele KE. Submuscular bridge plating for length-unstable, pediatric femur fractures. *J Pediatr Orthop.* 2013 Dec;33(8):797-802.
- Kuremsky MA, Frick SL. Advances in the surgical management of pediatric femoral shaft fractures. *Curr Opin Pediatr.* 2007 Feb;19(1):51-7.
- Flynn JM, Schwend RM. Management of pediatric femoral shaft fractures. *J Am Acad Orthop Surg.* 2004 Sep-Oct;12(5):347-59.
- National Institute for Clinical Excellence (NICE). Limb and joint fractures in hospital: trauma pathway. <http://pathways.nice.org.uk/pathways/trauma>; July 2018 Last Accessed 28 Sept 2018.
- Samora WP, Guerriero M, Willis L, Klingele KE. Submuscular bridge plating for length-unstable, pediatric femur fractures. *J Pediatr Orthop.* 2013 Dec;33(8):797-802.
- Jain A, Aggarwal A, Gulati D, Singh MP. Controversies in orthopaedic trauma--management of fractures of shaft of femur in children between 6 and 12 years of age. *Kathmandu Univ Med J (KUMJ).* 2014 Jan-Mar;12(45):77-84.
- Flynn JM, Hresko T, Reynolds RA, Blasler RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. *J Pediatr Orthop.* 2001 Jan-Feb;21(1):4-8.
- Schatzker J: Preoperative Planning. In Rüedi TP, Murphy WM (eds). *AO Principles of Fracture Management.* Stuttgart, Thieme 121-137, 2000.
- Edwards TA, Daly C, Donovan RL, Whitehouse MR. Risk of complications following surgical fixation of femoral diaphyseal fractures in children aged 4 to 12 years: A systematic review and meta-analysis. *Injury.* 2022 Mar;53(3):1020-1028.
- Abdelgawad AA, Sieg RN, Laughlin MD, Shunia J, Kanlic EM. Submuscular bridge plating for complex pediatric femur fractures is reliable. *Clin Orthop Relat Res.* 2013 Sep;471(9):2797-807.
- Kanlic EM, Anglen JO, Smith DG, Morgan SJ, Pesántez RF. Advantages of submuscular bridge plating for complex pediatric femur fractures. *Clin Orthop Relat Res.* 2004 Sep;(426):244-51.
- Allen JD, Murr K, Albitar F, Jacobs C, Moghadamian ES, Muchow R. Titanium Elastic Nailing has Superior Value to Plate Fixation of Midshaft Femur Fractures in Children 5 to 11 Years. *J Pediatr Orthop.* 2018 Mar;38(3):e1111-e1117.
- Caglar O, Aksoy MC, Yazici M, Surat A. Comparison of compression plate and flexible intramedullary nail fixation in pediatric femoral shaft fractures. *J Pediatr Orthop B.* 2006 May;15(3):210-4.
- Wang W, Zheng X, Sun Z. Comparison of efficacy between internal fixation of minimally invasive elastic stable intramedullary nail and plate in the treatment of pediatric femoral shaft fracture. *Pak J Med Sci.* 2019 Sep-Oct;35(5):1417-1421.
- Reddy R, Reddy S, Uniyal P, and Reddy R. Comparative Study Between Titanium Elastic Nailing (Tens) and Dynamic Compression Plating (DCP) in the Treatment of Femoral Diaphyseal Fractures in Children. *J. Evol. Based Med. Health.* 2015; 2 (32): 4822-4835.
- Milligan D, Henderson L, Tucker A, Ballard J. Elastic nail fixation versus plate fixation of paediatric femoral fractures in school age patients - A retrospective observational study. *J Orthop.* 2019 Nov 27;19:153-157.
- Xu Y, Bian J, Shen K, Xue B. Titanium elastic nailing versus locking compression plating in school-aged pediatric subtrochanteric femur fractures. *Medicine (Baltimore).* 2018 Jul;97(29):e11568.
- Sanjay N, Seenappa H, Shanthappa AH, Kumar K V. Functional Outcome of Pediatric Subtrochanteric Fractures Treated With a Titanium Elastic Nailing System (TENS) Versus Plating. *Cureus.* 2023 Jun 6;15(6):e40036.
- Ho CA, Skaggs DL, Tang CW, et al. Use of flexible intramedullary nails in pediatric femur fractures. *J Pediatr Orthop* 2006;26: 497-504.