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Is Nail Dynamization Useful In Delayed Union of Tibial Shaft Fractures? A Systematic Review and Meta-Analysis

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Abstract

Background: Nail dynamization is a controversial strategy used to treat delayed union in tibial shaft fractures. Reported union rates of nail dynamization varies within a wide range that goes from 19% to 100%. The purpose of this study was to perform a systematic review and a meta-analysis of the literature to explore post-dynamization union rates in cases of delayed union of tibial fractures following locked intramedullary nailing.

Methods and Findings: This systematic review was conducted following the PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analyses) guidelines. We searched the Cochrane Database, PubMed, and the first 100 references of Google Scholar to June 2020. Inclusion criteria were as follows: English-language original research articles that included patients over 14 years of age with tibial shaft fractures treated with locked intramedullary nailing and posterior dynamization of static screws. Methodology quality was assessed using a modified version of Coleman's score.

We identified 14 studies that included 1198 fractures for full analysis. The mean age was 35.8 (range; 14-82 years) and the average follow-up period was 27 months (range; 3-100). Statically locked intramedullary nails were found in 922 (76.9%) fractures. Dynamization was reported

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for 260 fractures (28.2%) with an overall union rate of 89.6%. Our meta-analysis showed a weighted effect size of 95.1% (CI95% 83.5 - 98.6%) regarding union after the dynamization.

Conclusions: This meta-analysis demonstrates that nail dynamization represents an effective treatment strategy in delayed union of tibial shaft fractures. High union rates (up to 95%) can be achieved with this procedure.

Keywords

Dynamization; Delayed Union; Intramedullary Nailing; Tibial Fracture

Introduction

Tibial shaft fractures are the most common long-bone fractures. Since its Introduction, Intramedullary Nailing (IMN) has become the treatment of choice for most of them [1].

The reported union rates achieved with IMN are 90-100% [2-4]. The rate of complications like delayed union (a complication attributed to fracture morphology, soft tissue damage, and the surgical technique used) goes up to 40% [5-7].

Nailing exchange, fibular osteotomy and dynamization (either as single or combined procedures) are some of the available treatment options to deal with these complications [8-12].

Dynamization consists in the removal of a statically locked screw to allow controlled transmission of axial loads to the fracture site. This enhances bone contact between bone fragments, stimulating osteogenesis [8,13-14].

The reported union rate of nail dynamization varies from 19% to 100% [13-15]. Although it is a widely used strategy to treat delayed union in tibial fractures, there is not enough evidence in the literature supporting its use. Most of the studies found are retrospective and conducted on a small series of patients [4,6,8,14].

The purpose of this study was to perform a systematic review and meta-analysis of the existing literature to explore the union rates after dynamization in delayed union of tibial shaft fractures.

Methods

Article Selection

This study followed the PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analyses Meta-analysis) guidelines published in 2009 [16]. We conducted a systematic review of the literature on the dynamization of static tibial intramedullary nails, assessing timing of procedure, and union rates.

Inclusion Criteria

Studies had to meet the following criteria:

- Shaft tibial fracture treated with locked intramedullary nailing
- Dynamization
- Patients over 14 years old
- Description of outcomes and union rates
- English Language

Whenever delayed union and non-union were described together, the information on the latter was excluded. Other exclusion criteria involved: pathological fractures and patients undergoing secondary procedures (in addition to dynamization) like bone grafting or fibular osteotomy. Systematic reviews, editorials, biomechanical or animal studies as well as analyses conducted on the same population in different papers or duplicated articles were also excluded.

Search Strategy

A systematic review of the literature was performed in the Cochrane Database, PubMed, and Google Scholar (using the first 100 references listed), including all available studies to June 2020 (i.e., the date of the search).

The literature search strategy included the following key words: “tibia” or “tibial” [All Fields] and “fracture” [All Fields] and “intramedullary nail” [All Fields] or “nail” [All Fields] or “IMN” [All Fields] and “delayed union” [All Fields] and “dynamization” [All fields] or “screw” [All Fields].

Information gathering and processing

Selected studies were recorded by 3 independent authors who analyzed the level of evidence according to the method described by Wright, et al., [17].

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Author or publication provenance was not considered. Controversies were resolved by consensus under the supervision of a senior author.

Whenever union rate information was missing in the papers, we contacted first authors to complete the register [18].

Information was extracted from full text articles. We registered demographical data (gender, age), type of fracture, nail design and failure rate.

We documented time (weeks) between primary intramedullary nailing and screw removal and between screw removal and bone union.

Whenever mean or Standard Deviation (SD) values were not available for analysis, these values were obtained from other reported measurements (median, range, and interquartile ranges). All data were registered in an Excel sheet (Microsoft™, Redmon, WA).

Literature Quality Assessment

We used a modified version of Coleman's Score (mSC) to assess the methodological quality of each study [19]. This score consists of two subgroups: Section A included an assessment of study size, follow-up (in months), type of study, diagnostic certainty, procedure description and fracture characteristic. Section B assessed outcome criteria, outcome assessment, and description of patient selection processes. Each item was rated with a single score for sub-section A. For sub-section B more than one score may be given for each option if applicable. The maximum possible score was 100, which would mean that the study has a small chance of presenting bias or confounding factors.

Statistical Analysis

Results are presented for each individual study as number of events (dynamizations and healed fractures) and proportion. We used a random effect model to assess outcomes due to the variability between studies.

Heterogeneity was assessed using Cochran's Q test (considering a p-value of <0.10 as statistically significant) and measuring I^2 , which estimates inconsistency (percentage of variation between studies due heterogeneity rather than chance).

Values >75% were considered highly inconsistent. Publication bias was evaluated using a funnel plot and asymmetry was calculated using Egger's test, considering a p-value of <0.10 as statistically significant (Table 1).

The statistical analysis was performed using the software R. 3.6.1. (Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria).

Modified Coleman's Score	
Section A - Single score for each of the items	
Sample Size	
>60	10
41-60	7
20-40	4
<20	0
Mean Follow-up	
>24m	5
12 - 24m	2
<12m	0
Fracture description (type - location - open closed)	
Reported	5
Non reported	0
Number of reported procedures about an outcome	
Single procedure	10
More than one procedure but 90% it's the same.	7
Non reported o not specified o <90% of sample with same procedure	0
Type of study	
Randomized	15
Prospective cohort	10
Retrospective cohort	5
Diagnostic certainty in dynamized nails	
Reported	5
Non reported	0
Procedure description	
Suitable (Technique and procedure details)	5
Fair (Reported but no details described)	2
Non suitable, non-reported or no clear	0
Section B- Score may be given for each option in each of the three sub-section if applicable.	
Outcome criteria - Dynamized nails	
Outcome measure clearly defined	4
Timing of outcome assessment clearly stated	5
Use of outcome score that has reported reliability	6

Processing of assessing outcomes	
Participants recruited	6
Investigator independent of surgeon	5
Written assessment	4
Description of patient selection process	
Selection criteria reported and unbiased	5
Recruitment rate reported > 80% o < 80%	5 o 3
Non included Eligible patients well represented	5

Table 1: Modified Coleman's Score.

Results

The initial search strategy identified 769 articles. After applying inclusion and exclusion criteria and removing duplicated papers, only 34 studies were available for analysis. After detailed reading, 14 articles were kept (Fig. 1).

Figure 1: PRISMA selection of eligible studies flow diagram.

Characteristics and Demographics of Selected Studies

The information extracted from these 14 studies included demographic information, gender, age, fracture location and type of fracture (open or closed) (Table 2).

Researchers included 1198 fractures (range; 15-141) in 1196 patients; 887 (74%) were male. The mean age was 35.8 years (range; 14-82) and the mean follow-up period was 27 months (range; 3-100). There were 780 (65.1%) closed fractures. The most common open fracture reported was type 1 (Gustilo-Anderson classification) with one hundred sixty-three (38.9%) fractures.

Regarding fracture morphology (AO/ASIF classification), of the 922 dynamized fractures, 902 (97.8%) were described. We identified 448 (49.7%) subtype A, 326 (36.1%) subtype B and 128 (14.2%) type C. Fifty percent of the described the implanted nail and three reported an intact fibula in their studies [15,20-22,24,26,29].

The analysis was carried out in 922 (76.9%) fractures that were initially treated with a statically locked intramedullary nail.

The 276 (23.1%) remaining fractures were excluded for being initially treated with dynamization.

Ten studies reported both open and closed fractures, two described the treatment provided for open fractures only, 15, 30 and two papers described closed fractures only [6, 14, 20-28].

All articles reported the number of patients undergoing this procedure. The overall dynamization rate was 28.2% (260 of 922). In two studies, we could not determine whether the secondary procedure was performed due to delayed union or non-union [6, 26]. The details about treatment, dynamization and union rates are reported in Table 3.

Series	Journal	Year	LOE	Age	Fracture (n)	Male	Female
Koval, et al. ²⁰	Journal of Orthopaedic Trauma	1991	IV	28 (14-63)	60	38	18
Riemer, et al. ²¹	Journal of Orthopaedic Trauma	1995	IV	34 (16-80)	67	54	11
Stegeman, et al. ¹⁵	Journal of Orthopaedic Trauma	1995	IV	34 (17-79)	41	29	12

Greitbauer, et al. ²²	Clinical Orthopaedics and Related Research	1998	IV	39 (15-84)	70	43	25
Ali Djahangiri, et al. ²³	Medical Principles and Practice	2006	IV	43.6 (18-72)	96	65	31
Drosos, et al. ²⁴	The Journal of Bone & Joint Surgery (Br)	2006	IV	34.4 (14-87)	161	119	42
Giri, et al. ²⁵	Nepal Medical College Journal	2008	IV	32 (18-65)	55	40	15
Chalidis, et al. ²⁶	Strategies of Trauma and Limb Reconstruction	2009	IV	38.9 (17-95)	217	175	58
Burc, et al. ²⁷	Acta Orthopaedica et Traumatologica Turcica	2009	III	31 (17-68)	73	68	5
Kamruzzaman, et al. ²⁸	Bangladesh Medical Journal	2011	IV	35 (25-65)	29	24	10
Hernandez-Vaquero et al. ²⁹	International Journal of the Care of the Injured	2012	IV	40.6	67	51	16
Agrawal et al. ³⁰	Journal of Clinical and Diagnostical Research	2013	IV	NA	30	NA	NA
Litrenta et al. ⁶	Journal of Orthopaedic Trauma	2015	III	39 (16-81)	194	149	45
Perumal et al. ¹⁴	Journal of Clinical Orthopaedics and Trauma	2017	IV	36 (16-63)	38	32	5
					1198	887	293

LOE: Level of Evidence; NA: Not Available								(Continues)
Follow-up (months)	Close d	Ope n	Gustilo I/II/III	AO/ASIF			Intact Fibula	Nail Design
				A	B	C		
60	48	12	11/1/2000	NA	NA	NA	17	16 AO Synthes Paoli (PA, USA) / 42 Grosse-Kempf (Rutherford, N.J, USA) /Russell-Taylor (Smith & Nephew Richards, Memphis, TN, USA)
26 (5-50)	26	41	6/7/2028	29	24	14	NA	16 AO Synthes Paoli (PA, USA) / 51 Alta Nail (Howmedica, Rutherford, NJ, USA)
15	-	41	15/12/14	19	15	7	NA	41 AO Synthes Paoli (PA, USA)
36	42	28	7/8/2013	24	31	15	8	Solid Tibial Nail / HowMedica, Rutherford, NJ, USA)
18	70	26	15/11/00	64	18	14	NA	NA
13.3 (4- 60)	137	24	NA	97	54	10	8	Russel-Taylor, S&N, Memphis, TN, USA)
8.5 (3-14)	55	-	-	-	-	-	NA	NA
58.8	190	27	18/3/06	118	90	39	NA	Russel-Taylor, S&N, Memphis, TN, USA)
48 (24- 60)	28	45	30/10/05	28	29	16	NA	NA
24	29	-	NA	15	14	0	NA	NA
12 (12- 20)	51	16	16/0/0	35	32	0	NA	Grosse-Kempf (Stryker, Kalamazoo,MI,USA)
24	-	30	10/7/2013	3	7	3	NA	NA
15	75	119	29/33/58	NA	NA	NA	NA	NA
12	29	9	6/3/2000	16	12	10	NA	NA
	780	418	163/95/137	448	326	128		

IMN: Intramedullary Nailing; NA: Not Available

Table 2: Studies description (continues).

Studies	Fracture with static mode of IMN	Causes that lead dynamization	Dynamization (n - %)	Time of dynamization (weeks)	Union (weeks, %)	Mean time till union
Koval et al. ²⁰	31	Delay union	19 (61.3%)	13.1 (5-20)	18 (94.7%)	NA
Riemer et al. ²¹	50	Delay union - nonunion	13 (26%)	24 (9-49)	12 (9.3%)	15 (4-39)
Stegeman et al. ¹⁵	15	No sign of union at 6-8 weeks	5 (33%)	8	5 (100%)	24 (13-48)
Greitbauer et al. ²²	70	Delay union	1 (1.42%)	28	1 (100%)	15 (8-40)
Ali Djahangiri et al. ²³	96	Delay union	48 (50%)	12	48 (100%)	18 (16-22)
Drosos et al. ²⁴	141	Delay union	24 (17%)	NA	24 (100%)	41.3 (24-52)
Giri et al. ²⁵	55	Delay union	1 (1.8%)	NA	1 (100%)	16
Chalidis et al. ²⁶	217	No sign of union at 10-12 weeks	22 (10.1%)	11 (10-12)	18 (83%)	NA
Burc et al. ²⁷	45	Delay union	4 (8.88%)	18 (16-24)	4 (100%)	NA
Kamruzzaman et al. ²⁸	29	Delay union	4 (13.8%)	<12	4 (100%)	NA
Hernandez-Vaquero et al. ²⁹	35	Delay union	2 (5.7%)	NA	2 (100%)	NA
Agrawal et al. ³⁰	30	No sign of union at 6 - 10 weeks	9 (32.1%)	8 (6-10)	4 (44.4%)	24
Litrenta et al. ⁶	88	Delay union - nonunion	88 (100%)	22.4	73 (83%)	44.4
Perumal et al. ¹⁴	20	No progressive sign of union on two consecutive visits	20 (100%)	19.1 (12-36)	19 (95%)	24
Total / Mean	922		260	15.9	233	24.6

Table 3: Patients details that underwent dynamization.

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Time to Dynamization and Union

Eleven studies (78.6%) described the time between primary intramedullary nailing and static screw removal as a mean period of 15.9 weeks (range; 5-49) [6,14,15,20-23,26-28,30]. In five (45.4%) of them, static screws were removed before week 12 after nailing (mean interval of 10.2 weeks) and in the 6 remaining studies the procedure was performed after that timepoint (mean interval of 20 weeks) [6,14,15,20-22,23,26,27,28,30].

Eight papers reported union rates of 100% and three over 90% [14,15,20-25,27-29].

A grouped analysis of the studies showed that the overall union rate was 89.6%. Our meta-analysis showed a weighted effect size of 95.1% (CI 95% 83.5-98.6) regarding union after dynamization with a moderate inconsistency ($I^2=74\%$), though without statistically significant heterogeneity ($p=0.58$) (Fig. 2). In our analysis, we did not calculate an average value; rather we relied on the weight of individual studies and estimated the resulting weighted effect.

We did not observe statistically significant differences associated with the time of dynamization, i.e., before or after twelve weeks (89.8% versus 87.5%; $p=0.68$).

Nine (64.2%) papers clearly reported the interval between static screw removal and bone healing as a mean period of 24.6 weeks (range: 4-41.3) [6,14,15,21-25,30]. There were no statistically significant differences as regards union rates between patients undergoing dynamization before and after twelve weeks (16.7 ± 8.8 versus 24.0 ± 12.0 ; $p=0.32$).

Figure 2: Meta-analysis of proportion.

Failures

Six studies described 27 (10.4%) failures [6,14,20,21,26,30]. Riemer, et al., Kova, et al., and Perumal, et al., reported one case of non-union each [14,20,21]. Agrawal's group reported five (55.55%) failures after dynamization [30]. Two studies described non-union but did not include information on their evolution [6,26]. The treatment modalities reported in each study for failures are detailed in Table 4.

Studies	n (%)	Treatment
Koval, et al. ²⁰	1 (2.77%)	Nail exchange
Riemer, et al. ²¹	1 (2.77%)	Nail exchange
Perumal, et al. ¹⁴	1 (2.77%)	Non-surgical
Chalidis, et al. ²⁶	4 (18.18%)	Not reported
Agrawal, et al. ³⁰	5 (55.55%)	4 Autologous bone grafting / 1 Amputation
Litrenta ⁶	15 (17%)	Not reported

Table 4: Dynamization failure rate and treatment.

Publication Bias

We observed graphical publication bias. The results of formal asymmetry tests were not statistically significant ($p=0.19$) (Fig. 3).

Figure 3: Funnel plot.

Literature Quality Evaluation

After assessing the methodological quality of selected studies, the mean mCS was 61.14 (range; 42-76).

Discussion

Since the introduction of locked intramedullary nailing, delayed union and non-union rates have decreased considerably. However, these complications are still reported with different rates [31-33].

Nail dynamization is one of the first strategies to treat delayed bone healing [34]. Although this is a common and simple procedure, there is not enough evidence in the literature supporting it. In addition, some report delayed union and non-union rates without differentiating between femur and tibial fractures, even when the physiological behavior of these fractures is different [14].

In this study, we assessed tibial shaft fractures initially treated with a statically locked intramedullary nail followed by dynamization as a consequence of delayed union.

Our data analysis showed that the rate of tibial fractures requiring this secondary procedure was over 28%, which proves dynamization is a frequently used treatment strategy.

We failed at characterizing fracture types that could require or benefit from dynamization because the articles selected did not clearly describe this kind of information. Most fractures reported were subtypes A and B according to the AO/ASIF classification (both with an incidence of 86%).

Several authors agree that dynamization is not a safe procedure in comminuted or large oblique fracture patterns, due to the risk of shortening and malalignment [34,35].

Though, after a detailed analysis of the bibliography, we observed that this loss of longitudinal and rotational stability (granted by the interlocking nail) occurs more frequently when the dynamization involves the removal of all the screws on one side of the fracture [6].

On the other hand, we were able to observe that static screw removal is described as a simple and non-demanding surgical technique, with low morbidity rates, and less costly than other strategies, like nail exchange [36].

As for the time of dynamization after primary nailing, we observed a wide range of periods (ranging from 5 to 49 weeks), with a mean of 15.9 weeks. When comparing the studies that performed dynamization before and after twelve weeks, we did not find statistically significant differences in the union rates achieved. Therefore, we could not define the ideal time for screw

removal. Our results suggest that there is not enough evidence to establish an association between bone healing and the time of dynamization.

The most important finding of our study was that dynamization resulted in high rates of bone union (mean 89.6%) When we performed the meta-analysis, the union-weighted effect size increased to 95.1%.

The studies reporting the lowest union rates were the ones published by Agrawal, Chalidis and Litrenta, et al., [6,26,30]. The first one analyzed 30 open fractures and observed a linear relationship between severity and union rates after dynamization; most of their failures were in Gustilo 3B fractures.

Chalidis' study reported dynamization procedures but did not describe fracture characteristics and, therefore, it was difficult for us to analyze failure [22,26]. Finally, Litrenta, et al., compared screw removal and nailing exchange in delayed unions and non-unions but did not provide sufficient information about fracture types to establish differences between both treatments [6]. They also stated that the presence of a gap in the fracture site was a predictor of failure for both procedures.

The limitations of this study include the fact that a vast percentage of the studies included were conducted on case series with a high risk of confounding or publication bias. Also, it is possible that we were not able to identify some relevant studies with our search criteria.

To the best of our knowledge, this is the first systematic analysis that assesses effectiveness of dynamization in delayed union of tibial shaft fractures.

Conclusion

The results of this meta-analysis suggest that nail dynamization is a reliable treatment strategy for delayed union in tibial shaft fractures with relatively high union rates. We need properly designed studies with high statistical strength to assess the effectiveness of this procedure.

Ethics Approval

All procedures performed in this study, which involved the use of data from human participants, were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments. The Ethics committee of our hospital determined that the approval of this type of study is not required.

Conflict of Interest

There is no conflict of interest following this study.

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