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Difference in Pain, Complication Rates, and Clinical Outcomes After Suprapatellar Versus Infrapatellar Nailing for Tibia Fractures? A Systematic Review of 1447 Patients

Nils Jan Bleeker, MD,[a] Inge H. F. Reininga, PhD,[a] Bryan J. M. van de Wall, MD, PhD, MSc,[b] Laurent A. M. Hendrickx, MD,[c,d] Frank J. P. Beeres, MD, PhD,[b] Kaj ten Duis, MD,[a] Job N. Doornberg, MD, PhD,[a,c] Ruurd L. Jaarsma, MD, PhD, FRACS,[c] Gino M. M. J. Kerkhoffs, MD, PhD,[d] and Frank F. A. IJpma, MD, PhD[a]

Objectives: To assess the effectiveness of suprapatellar (SP)-nailing versus infrapatellar (IP)-nailing of tibia fractures in anterior knee pain, complications (retropatellar chondropathy, infection, and malalignment) and physical functioning and quality of life. A clinical question-driven and thorough systematic review of current literature is provided.

Data source: PubMed and Embase databases were searched for studies published between 2010 and 2020 relating to SP and IP-nailing of tibia fractures. The study is performed in concordance with PRISMA-guidelines.

Study selection: Studies eligible for inclusion were randomized controlled trials, prospective and retrospective observational studies reporting on outcomes of interest.

Data extraction: Data extraction was performed independently by 2 assessors. Methodological quality and risk of bias was assessed according to the guidelines of the McMaster Critical Appraisal.

Data synthesis: Continuous variables are presented as means with SD and dichotomous variables as frequency and percentages. The weighted mean, standardized weighted mean differences, and 95% confidence interval were calculated. A pooled analysis could not be performed because of differences in outcome measures, time-points, and heterogeneity.

Results: Fourteen studies with 1447 patients were analyzed. The weighted incidence of anterior knee pain was 29% after SP-nailing and 39% after IP-nailing, without reported significance. There was a significant lower rate of malalignment after the SP-approach (4% vs. 26%) with small absolute differences in all planes. No substantial differences were observed in retropatellar chondropathy, infection, physical functioning, and quality of life.

Conclusions: This systematic review does not reveal superiority of either technique in any of the respective outcomes of interest. Definitive choice should depend on the surgeon's experience and available resources.

Key Words: intramedullary nailing, tibia fractures, suprapatellar, infrapatellar, anterior knee pain, complications, physical functioning, general quality of life

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

The number of good quality studies evaluating suprapatellar (SP) nailing of tibia fractures is rising, and the SP-approach gained popularity in the field of orthopaedic trauma as an alternative surgical approach for tibia fractures. The SP-approach was first described by Tornetta et al[1,2] and a modified technique was described by Cole[3] in 2006. Early reports suggest potentially less anterior knee pain as the main advantage, with incidences up to 71% reported after traditional infrapatellar (IP) approach.[4–7] Second, straightforward positioning with less flexion of the knee may lead to better alignment control and lower rates of malalignment.[8–10] On the contrary, the SP-approach may lead to iatrogenic damage of the intra-articular structures of the knee[11–15] and potentially an increased risk for infection,[16,17] because the nail will be introduced superior of the proximal patellar pole and passes the articular surface.

The potential superiority of SP-approach for intramedullary nailing (IMN) of the tibia is subject of ongoing debate.[18–22] Since its introduction, early results were considered to be promising in anterior knee pain,[23–26] optimal

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From the [a]Department of Orthopaedic Trauma Surgery, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands; [b]Department of Orthopaedic Trauma Surgery, Cantonal Hospital Lucerne (LUKS), Lucerne, Switzerland; [c]Department of Orthopaedic Trauma Surgery, Flinders Medical Centre, Adelaide, Australia; and [d]Department of Orthopaedic Surgery, Amsterdam University Medical Centers, Amsterdam Movement Sciences (AMS), University of Amsterdam, Amsterdam, the Netherlands.

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Reprints: Nils Jan Bleeker, MD, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, the Netherlands 1055TM (e-mail: nilsjanbleeker@gmail.com).

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alignment control,[8–10,14,24] physical functioning,[23,24,26] and general quality of life (QoL).[23,26,27] However, other studies found no differences in anterior knee pain and functional outcomes if compared to IP-nailing.[10,12,28] Furthermore, data on theoretical concerns regarding retropatellar chondropathy and infection rates after the SP versus IP-approach are scarce. The most recent systematic review on this subject was published in 2019 in this Journal[20] and concluded that the SP-approach results in less pain and better functional outcomes if compared with IP-approach. The literature search of this systematic review was performed until august 2018, and resulted in the inclusion of 5 studies. However, over the last decade, several more good quality studies [both randomized controlled trials (RCT's) and cohort studies] reporting on pain, complications, physical functioning, and general QoL were published on SP versus IP-approach for nailing of tibia fractures that improves our understanding and contribute to the ongoing debate.

Therefore, this systematic review on SP versus IP-nailing provides an update with inclusion of these additional studies with the aim of answering the following clinical research questions: (1) does the SP versus IP-approach result in less anterior knee pain?; (2) does the SP versus IP-approach influence complication rates (retropatellar chondropathy, infection, malalignment, nonunion, and subsequent surgeries)?; and (3) does the SP versus IP-approach affect physical functioning and QoL?

MATERIAL AND METHODS

This systematic review was conducted and written in concordance with the Preferred Reporting Items for Systematic Reviews (PRISMA).[29] The protocol of this systematic review is registered in the international PROSPERO-database (CRD42020181854).

Objectives and Study Sources

The PubMed and Embase databases were searched on 23-04-2020 for articles published between 2010 and 2020 relating to tibia fractures, IMN, and nailing technique (SP and IP). A medical librarian constructed the search strategy, which is presented in **Supplemental Digital Content 1** (see **Table**, http://links.lww.com/JOT/B319).

Study Selection

Studies eligible for inclusion were RCT's, prospective and retrospective observational studies reporting on: (1) tibia fractures; (2) IMN; (3) nailing technique; (4) anterior knee pain; (5) complications [retropatellar chondropathy, infection, malalignment, non-union, subsequent surgeries and range of motion (ROM)]; (6) physical functioning and QoL, assessed with patient-reported outcome measures (PROMs); (7) minimal follow-up of 6 months; and (8) patient's age ≥18 years. Studies were excluded in case of: (1) pediatric fractures; (2) animal studies; (3) case reports, conference abstracts, systematic reviews or meta-analyses; (4) surgical treatment other than IMN; and (5) language other than English, German, Dutch, French and Spanish.

Study selection was executed in duplicate by N.J.B. and F. IJ. and performed in 2 stages with use of Rayyan software.[30] In stage 1, title and abstract were screened. In stage 2, full text screening was performed. Disagreement was resolved by discussion according to the Cochrane Handbook for Systematic Reviews of Interventions.[29]

Data Extraction

Methodological quality and risk of bias of included studies was independently assessed by N.J.B. and I.H.F.R. according to the guidelines of the McMaster University Occupational Therapy Evidence-Based Practice Research Group.[31] The McMaster critical appraisal consists of 8 categories including: (1) study purpose; (2) literature review; (3) study design; (4) study sample; (5) study outcome; (6) study intervention; (7) study results; and (8) conclusions and implications. Scores included: "yes = 1 point," "no = 0 points," "not addressed (N/A)," and "not applicable (NA)." The total score reflects the methodological quality with a maximum score of 16 for RCT's and 14 for other designs. The definitive score may vary from 0% to 100%, with a higher score indicating a higher methodological quality. Scores between 75% and 89% indicated good-quality studies and scores between 90% and 100% indicated excellent-quality studies. Based on the quality of the studies, a best-evidence synthesis was performed. Any continued disagreements were solved during a consensus meeting with N.J.B., I.R., and F.F.A.I.

Data extraction was performed independently by N.J.B. and F.F.A.I. using a predefined extraction file. Patient demographics, study details, OTA/AO classification,[32] follow-up duration, and outcome measures of interest were extracted from included studies.

Surgical Technique

The SP-approach encompasses 2 surgical techniques described by respectively Ryan[33] and Sanders et al[14] Ryan et al[33] describes an incision in the midline to the superior pole of the patella. Using this incision as a mobile window, a partial medial parapatellar arthrotomy is performed. The entry-point is reached by subluxating the patella laterally. The technique described by Sanders et al[14] uses a longitudinal incision proximal of the superior pole of the patella. The entry point is reached by splitting the distal quadriceps and lifting the patella. The knee is 20–30 degrees flexed and potential damage to the intra-articular structures of the knee is avoided using a sleeve.[34] The entry point at the anteromedian side of the proximal tibia is determined under fluoroscopy assistance.[34]

The traditional IP-approach encompasses 3 main surgical approaches distal of the inferior pole of the patella, including the medial parapatellar, lateral parapatellar, and tendon-splitting approach. The definitive choice depends on the surgeon's preference and is usually not reported on in studies. The knee is positioned in 90 degrees flexion. The longitudinal incision is made from the distal pole of the patella toward the tibia tubercle. The entry point for the intramedullary nail is equal to the SP-approach.

Definition(s) of Outcome Measures

Anterior knee pain is defined as discomfort located anteriorly of the affected knee, which occurred after tibia

nailing. Anterior knee pain is presented as a percentage of patients experiencing knee pain, or objectified with use of PROMs. The PROMs reporting on pain are listed in **Supplemental Digital Content 2** (see **Supplemental Digital Content 2,** http://links.lww.com/JOT/B320).

Complications include retropatellar chondropathy, infection, malalignment, nonunion, subsequent surgeries, and impaired ROM of the knee joint. Retropatellar chondropathy is defined as iatrogenic damage to the patellofemoral joint after SP-nailing detected by peroperative arthroscopy and postoperative MRI of the knee. Infection is categorized into superficial and deep infections and encompassed septic arthritis.[35] Malalignment is divided into angular deformities in the coronal or sagittal plane and rotational malalignment. Angular deformities are defined as a deformity of ≥5 degrees in the coronal or sagittal plane[8,36,37] and rotational malalignment is defined as a rotation of ≥10 degrees in comparison to the unaffected side.[38,39] Nonunion includes no signs of cortical healing after 6 months. Subsequent surgeries include screw(s) removal, implant removal, and revision for complications. ROM is extracted as reported in included studies and includes the flexion and extension of the affected or/and unaffected knee joint.

PROMs encompassed multiple questionnaires reporting on 2 constructs, predefined for this study: (1) physical functioning; and (2) QoL. The different PROMs are described in **Supplemental Digital Content 2** (see **Supplemental Digital Content 2**, http://links.lww.com/JOT/B320).

Data Synthesis

Continuous variables are presented as means with SD and dichotomous variables as frequency and percentages. In case of more than 2 reported continuous variables in more than one group, the weighted mean and weighted SD was calculated. For dichotomous variables presented as frequency or percentage, the weighted mean frequency or percentage was calculated.

For comparative studies, the differences in continuous outcomes were calculated using the inverse variance weighting method and presented as standardized weighted mean difference (SMD) and 95% confidence interval (95% CI). Differences of dichotomous variables within comparative studies were calculated by use of the X^2-test according to the Cochrane Handbook for Systematic Reviews of Interventions.[40] *P*-values below 0.05 were considered to indicate statistical significance.

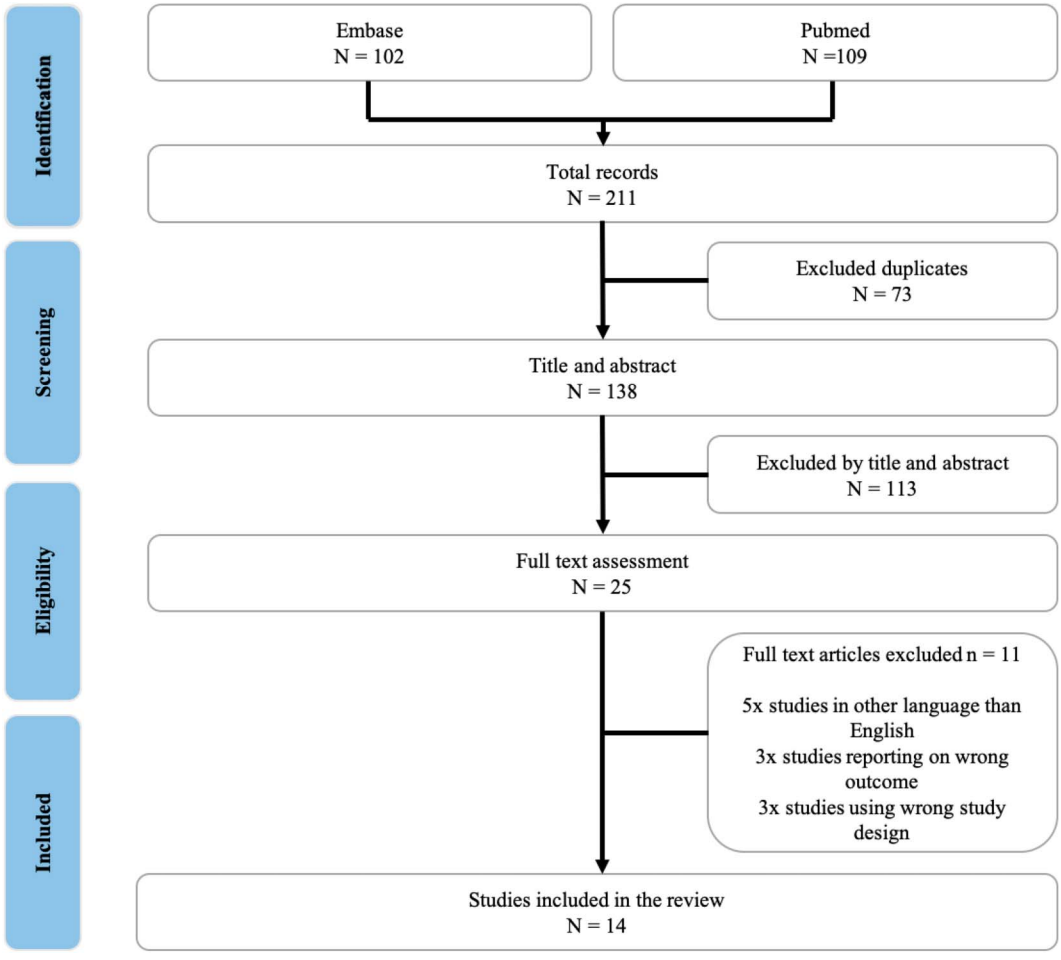

FIGURE 1. Search syntax. **Editor's Note**: A color image accompanies the online version of this article.

RESULTS

Search

The literature search resulted in 201 articles of which eventually 25 full-text articles were screened. A total of 14 studies met inclusion criteria and were eligible for further analysis (Fig. 1).[8–10,12,14,16,17,23,24,27,28,41–43]

Study Characteristics

A total of 1447 patients were included in this systematic review, including 760 fractures treated with the SP-technique and 700 fractures treated with the IP-technique (Table 1). Nine studies were comparative studies[8–10,12,16,27,28,41,43] and 4 noncomparative studies reporting on either the SP-approach[14,17,23,24] or IP-approach.[42]

Methodological Quality and Risk of Bias

There were 2 RCTs,[12,43] one prospective single cohort study,[14] 7 retrospective comparative cohort series,[8–10,16,27,28,41] and 4 retrospective single cohort series.[17,23,24,42] The mean overall score of RCT's was 94 (SD 0) and of other designs 75 (SD 7), respectively. The results of the methodological quality assessments are presented in **Supplemental Digital Content 3** (see **Table**, http://links.lww.com/JOT/B321).

Anterior Knee Pain

Eight studies reported on anterior knee pain, including 6 comparative studies[10,12,27,28,41,43] and 2 noncomparative studies (Table 2).[14,42] The weighted incidence of anterior knee pain was 29% after the SP-approach (range 0%–38%)[10,12,27] and 39% after the IP-approach (range 14%–46%).[10,12,27,42] No substantial differences were reported on Visual Analogue scale, Numeric Rating scale, and hospital special surgery score (HSS) pain scores & Lysholm pain scores for the SP-approach and IP-approach (Table 2).

Best-evidence synthesis showed that 5 of 8 studies that reported on knee pain were of good[10,28,42] or excellent quality.[12,43] MacDonald et al[43] reported a significant difference between the SP and IP-group in the AWT-K test after 12 months during fully weight-bear kneeling for 60 seconds. No other relevant differences were observed.

TABLE 1. Study Characteristics of Included Studies

Author	Year	Country	Design	N*	Period	Group(s) (n)†	OTA/AO-Classification	Outcomes	Follow-up‡ (Mean ± SD) SP	Follow-up‡ (Mean ± SD) IP
Avilucea et al[8]	2016	USA	RSC	266	2008–2014	SP (132) vs. IP (134)	43-A, 43-C1, 43-C2	Complications	>6	>6
Cazatto et al[23]	2018	Italy	RSC	25	2014–2016	SP (25)	42-A, 42-B, 42-C	Complications, physical functioning, QoL	29 (6)	NR
Chan et al[12]	2016	USA	RCT	25	2011–2012	SP (11) vs. IP (14)	42-A, 42-B, 42-C	Pain, complications, QoL	16 (5)	
Courtney et al[9]	2015	USA	RSC	45	2009–2013	SP (21) vs. IP (24)	42-A, 42-B, 42-C	Complications, physical functioning	8 (8)	13 (10)
Cui et al[41]	2019	China	RSC	50	2014–2016	SP (24) vs. IP (26)	42-A, 42-B, 42-C	Pain, physical functioning	24 (7)	23 (7)
Fu et al[24]	2016	China	RSC	23	2012–2013	SP (23)	41-A2, 41-A3, 42-A, 42-B, 42-C	Complications, physical functioning	16 (3)	NR
Isaac et al[28]	2019	USA	RSC	262	2011–2016	SP (91) vs. IP (171)	NR	Pain	43 (18)	50 (19)
Jones et al[10]	2014	UK	RSC	74	NR	SP (36) vs. IP (38)	42-A, 42-B, 42-C	Pain, complications, physical functioning, QoL	23 (6)	28 (5)
Leliveld et al[42]	2012	NL	RSC	71	1998–2008	IP (72)	42-A, 42-B, 42-C	Pain, complications, physical functioning	NR	84 (37)
MacDonald et al[43]	2019	UK	RCT	95	2011–2013	SP (53) vs. IP (42)	NR	Pain, complications, physical functioning	>6	>6
Marecek et al[16]	2018	USA	RSC	282	2009–2015	SP (147) vs. IP (142)	NR (open fractures)	Complications	9 (9)	11 (13)
Mitchell et al[17]	2017	USA	RSC	135	2011–2016	SP (139)	NR (open fractures)	Complications	9 (13)	NR
Ozcan et al[27]	2020	Turkey	RSC	58	2010–2017	SP (21) vs. IP (37)	NR	Pain, physical functioning	16 (4)	33 (19)
Sanders et al[14]	2014	USA	PSC	36	2007–2011	SP (37)	42-A, 42-B, 42-C	Pain, complications, physical functioning, QoL	19 (9)	NR

*Total patients.
†Total fractures.
‡Follow-up in months
RSC, retrospective cohort; PSC, prospective cohort; NR, not reported.

Complications

Two studies reported on retropatellar chondropathy after the SP-approach.[12,14] Chan et al[12] reported chondropathy in 3 of 11 (27%) patients based on pre- and post-SP-nailing arthroscopy. One had preexisting chondromalacia; one sustained small iatrogenic scratches of the trochlea, and one had some damage to the undersurface of the patella. All patients with post-SP-nail arthroscopic changes had a full recovery at 1-year follow-up. Sanders et al[14] reported grade II chondromalacia at the trochlea groove—probably because of pressure of insertion cannula—in 2 of 37 (5%) patients based on immediate arthroscopy after SP-nail insertion. Two patients exhibiting arthroscopic changes had normal MRIs at 1-year follow-up (Table 3).

Eight studies reported on infection,[12,14,16,17,23,24,42,43] including 3 good-quality studies[16,24,42] and 2 excellent-quality studies.[12,43] The weighted infection rate was 12% after the SP-approach (range 0%–18%)[12,14,16,17,23,24,43] and 9% after the IP-approach (range 0%–20%),[12,16,42,43] with most infections occurring after nailing of open fractures (SP 18% vs. IP 14%).[16,17] None of the patients included by Mitchell et al[17] developed septic arthritis of the knee after the SP-approach, whereas Marecek et al[16] reported 2 cases (1%) of 147 patients after the SP-approach.

Seven studies reported on alignment,[8–10,12,14,24,42] including 5 good- and excellent-quality studies.[8,10,12,24,42] Avilucea et al[8] reported 15% malalignment (40 of 266 patients) in the overall study population, with a significant difference between SP-group (5 patients, 4%) and IP-group (35 patients, 26%) ($P < 0.005$). The mean difference in alignment in comparison to the unaffected side in the coronal plane after SP-nailing was 3.2 degrees (SD 1.1 degree) versus 5.7 degrees (SD 1.8 degrees) after IP-nailing (SMD -1.7 degrees). The mean difference alignment in the sagittal plane was 2.9 degrees (SD 1 degree) versus 5.5 degrees (SD 2.3 degrees) after the IP-approach (SMD -1.5 degrees). Rotational malalignment was not reported. Courtney et al[9] reported significant differences in the sagittal plane (SMD 0.6 degrees) and Jones et al[10] reported significant differences in the coronal plane (SMD -0.6 degrees), both in favor of the SP-approach (Table 3).

Three studies reported on fracture healing[10,12,14] including one good-quality study[10] and one excellent-quality study.[12] The incidence of nonunion based on measurements on plain radiographs ranged from 1% to 9% after SP-nailing[10,12,14] and was 0% after IP-nailing[10,12] and did not statistically differ between the SP- and IP-approach (Table 3).

Eight studies reported on subsequent surgeries,[10,12,14,16,23,24,42,43] of which 6 studies were of good- to excellent-quality.[10,12,16,24,42,43] The weighted rate of

TABLE 2. Anterior Knee Pain After SP and IP Approach for Nailing of Tibia Fractures

Study and Outcome	Groups (n)	0–12 mo		>12 mo		*P*/SMD [95% CI]
		SP	IP	SP	IP	
Anterior knee pain						
Cases %						
Chan et al[12]	SP (11) vs. IP (14)	NR	NR	0 (0%)	2 (14%)	*P* 0.3
Jones et al[10]	SP (36) vs. IP (38)	NR	NR	12 (33%)	16 (42%)	*P* 0.4
Leliveld et al[42]	IP (71)	NR	NR	NR	27 (38%)	NA
Ozcan et al[27]	SP (21) vs. IP (37)	NR	NR	8 (38%)	17 (46%)	*P* 0.6
VAS						
Chan et al[12]	SP (11) vs. IP (14)	NR	NR	Mean 0.4	Mean 1.5	NA
MacDonald et al[43]	SP (53) vs. IP (42)	Mild 36; moderate 1; severe 0*	Mild 22; moderate 1; severe 0*	NR	NR	NA
Sanders et al[14]	SP (36)	NR	NR	0	NR	NA
Numeric Rating scale						
Isaac et al[28]	SP (91) vs. IP (171)	NR	NR	Kneeling 4 (4); resting 2 (3); walking 3 (3)	Kneeling 4 (4); resting 2 (3); walking 3 (3)	NA
AWT-K						
MacDonald et al[43]	SP (53) vs. IP (42)	36/37[1]	18/23[2]	NR	NR	NA
HSS pain score						
Cui et al[41]	SP (24) vs. IP (26)	NR	NR	29 (2)	28 (3)	SMD 0.4 [−0.2 to 0.9]
Lysholm pain score						
Chan et al[12]	SP (11) vs. IP (14)	NR	NR	24	20	NA
Sanders et al[14]	SP (36)	NR	NR	22	NR	NA

Visual Analogue scale (0 (no pain)– 10 (worst pain)), Numeric Rating scale (0 (no pain)–10 (worst pain)), AWT-K (Aberdeen weightbearing test)[1,2] Proportion of patients who completed the AWT-K as secondary outcome measurer of the test. HSS pain score (0 (complete discomfort)–100 (no discomfort)), Lysholm pain score (0 (heavy pain)–25 (no pain)).
*Mild (0–39), moderate (40–79), severe (80–100).
95% CI, 95% confidence interval; NR, not reported, NA, not applicable.

TABLE 3. Complications After SP- Versus IP-Nailing for Tibia Fractures

Complications	Study	Outcome(s)		*P*/SMD [95% CI]
		SP	IP	
Retropatellar chondropathy cases (%)				
	Chan et al[12]	3 (27%)	0 (0%)	*P* 0.1
	Sanders et al[14]	2 (5%)	NR	NA
Infection cases (%)				
	Cazatto et al[23]	0 (0%)	NR	NA
	Chan et al[12]	0 (0%)	0 (0%)	NA
	Fu et al[24]	0 (0%)	NR	NA
	Leliveld et al[42]	NR	Total 4 (6%); deep 1 (1%); superficial 3 (4%)	NA
	MacDonald et al[43]	2 (4%)	0 (0%)	*P* 0.4
	Marecek et al[16]	Total 24 (16%); deep 16 (11%); superficial 8 (5%)	Total 20 (14%); deep 14 (10%); superficial 6 (4%)	*P* 0.6
	Mitchell et al[17]	Total 25 (18%); deep 16 (12%); superficial 9 (7%)	NR	NA
	Sanders et al[14]	2 (5%)	NR	NA
Primary angular malalignment cases (%)				
	Avilucea et al[8]	5 (4%)	35 (26%)	$P < 0.005$*
	Chan et al[12]	1 (not specified)		NA
	Leliveld et al[42]	NR	3 (4%)	NA
	Sanders et al[14]	1 (3%)	NR	NA
(Mal)alignment coronal plane mean ± SD°				
	Avilucea et al[8]	3.2 degrees (1.1 degree)	5.7 degrees (1.8 degrees)	SMD -1.7 degrees* [−2 to 1.4 degrees]
	Courtney et al[9]	2.5 degrees (1.9 degrees)	3.2 degrees (2.0°)	SMD -0.4 degrees [−0.9 to 0.2 degrees]
	Fu et al[24]	1.6 degrees (1 degree)	NR	NA
	Jones et al[10]	1 degrees (0.8 degrees)	2 degrees (2.3 degrees)	SMD -0.6 degrees* [−1 to 0.1 degree]
(Mal)alignment sagittal plane mean ± SD°				
	Avilucea et al[8]	2.9 degrees (1 degree)	5.5 degrees (2.3 degrees)	SMD -1.5 degrees* [−1.7 to 1.2 degrees]
	Courtney et al[9]	2.9 degrees (2.6 degrees)	4.6 degrees (2.7 degrees)	SMD 0.6 degrees* [−1.2 to 0 degrees]
	Fu et al[24]	2.1 degree (1.3 degrees)	NR	NA
	Jones et al[10]	0 degrees (2.2 degrees)	0° (5.2 degrees)	SMD 0 degrees [−0.5 to 0.5 degrees]
Rotational (mal)alignment cortical width(s) in mm				
	Courtney et al[9]	0.3 (0.4)	0.3 (0.3)	SMD 0.2 [−0.4 to 0.8]
Non-union cases (%)				
	Chan et al[12]	1 (9%)	0 (0%)	*P* 0.4
	Jones et al[10]	1 (1%)	0 (0%)	*P* 0.5
	Sanders et al[14]	1 (3%)	NR	NA
Subsequent surgeries cases (%)				
	Cazatto et al[23]	6 (24%)	NR	NA
	Chan et al[12]	1 (9%)	0 (0%)	*P* 0.4
	Fu et al[24]	11 (48%)	NR	NA
	Jones et al[10]	1 (3%)	0 (0%)	*P* 0.5
	Leliveld and Verhofstad[42]	NR	44 (62%)	NA
	MacDonald et al[43]	13 (25%)	4 (10%)	*P* 0.1

TABLE 3. (*Continued*) Complications After SP- Versus IP-Nailing for Tibia Fractures

Complications	Study	Outcome(s)		*P*/SMD [95% CI]
		SP	IP	
	Marecek et al[16]	28 (19%)	30 (21%)	*P* 0.7
	Sanders et al[14]	7 (19%)	NR	NA
ROM F/E (flexion/ extension) mean arc ± SD				
	Chan et al[12]	F/E affected side 131 degrees/ 0.4 degrees	F/E affected side 137 degrees/ 0.8 degrees	NA
		F/E unaffected side 129 degrees/0.4 degrees	F/E unaffected side 138 degrees/0.8 degrees	
	Fu[24]	117.9 degrees (5.31 degrees)	NR	NA
	Sanders et al[14]	Affected side 124.2 degrees (SD NR)	NR	NA
		Unaffected side 127.2 degrees (SD NR)		

*Statistically significant.
NR, not reported; NA, not applicable.

subsequent surgeries was 21% after the SP-approach (range 3%–48%)[10,12,14,16,23,24,43] and 26% after the IP-approach (range 0%–62%).[10,12,16,42,43] None of the comparative studies[10,12,16,43] showed significant differences in rates of subsequent surgeries. A specification of subsequent surgeries is presented in **Supplemental Digital Content 4** (see **Table**, http://links.lww.com/JOT/B322).

Three studies reported on ROM (Table 3)[12,14,24] including one good-quality study[24] and one excellent-quality study.[12]

Fu et al[24] reported a significant difference between ROM preoperatively and postoperatively at last follow-up after SP-approach (26.7 vs. 117.9 degrees). Other studies reported no substantial differences in knee ROM between the affected and unaffected side at clinical follow-up (Table 3).[12,14]

Physical Functioning and General Quality of Life

Ten studies reported on physical functioning of the knee,[9,10,12,14,23,24,27,41–43] of which 5 studies were of good or excellent quality.[10,12,24,42,43] Only MacDonald et al[43] determined a statistically significant difference in Lysholm scores after 12 months between the SP and IP-approach (SMD 0.6) (Table 4). There were no differences observed with almost equal outcomes for the SP and IP-approach in international knee documentation committee (IKDC), Oxford knee score (OKS), Kujala Knee score, HSS, Olerud-Molander Ankle score (OMAS), and Irrgang scores (Table 4).

Four studies reported on general QoL[10,12,14,23] including 2 studies with good or excellent methodological quality.[10,12] No relevant differences were observed in SF-36 and SF-12 scores between the SP and IP-approach.

DISCUSSION

The rationale for choosing an SP instead of IP approach for IMN of tibial fractures is potentially less anterior knee pain. Clinical concerns of the SP-approach, however, may include iatrogenic damage to articular cartilage[11,13–15] and infection.[16,17] This is the first systematic review in which inclusion criteria were not limited by study design and that provides a comprehensive overview of current literature published over the last decade regarding complete spectrum of outcomes measures following SP or IP-nailing for tibia fractures.

This systematic review found no substantial decrease in the incidence of anterior knee pain regarding the SP- versus IP-approach (29% vs. 39%). In complications, only the rate of malalignment was significantly different (4% vs. 26%) with small absolute differences in the coronal and sagittal plane in favor of the SP-approach. No differences were observed in risk on retropatellar chondropathy, infection, nonunion, and subsequent surgeries. Self-reported physical functioning and QoL were comparable in both groups.

Does the SP Versus IP-Technique Result in Less Anterior Knee Pain?

The weighted incidence of anterior knee pain among studies after SP-nailing was 29% versus 39% after IP-nailing. There was a higher rate of anterior knee pain after IP-nailing; however, the studies that compared outcomes after SP to IP-nailing[10,12,27] reported no significant differences. The incidence of anterior knee pain ranged from 0% to 38% after SP-nailing and 14%–46% after IP-nailing.[10,12,27,42] The wide range may be explained by the multifactorial nature of anterior knee pain. Etiologies may include iatrogenic damage to the IP nerve,[42] to Hoffa's fat pad,[44] periosteal irritation of the entry point, patellar tendinopathy, or nail prominence.[45] Moreover, knee pain persists after nail removal in up to 60% of the cases.[5,42,46] It may be noteworthy that the IP-approach is used for implant removal, even after initial SP-nailing. Further research is needed to clarify the etiology of anterior knee pain and elucidate pain perception.

TABLE 4. Physical Functioning and QoL After the SP Approach Versus the IP Approach

Study and Outcome	Group(s)	0–12 mo		>12 mo		*P*/SMD [95% CI]
		SP	IP	SP	IP	
Physical functioning						
IKDC						
Cazatto et al[23]	SP (25)	NR	NR	77 (6)	NR	NA
OKS						
Cazatto et al[23]	SP (25)	NR	NR	42 (6)	NR	NA
Courtney et al[9]	SP (21) vs. IP (24)	36 (12)	40 (9)	NR	NR	SMD -0.4 [−0.9 to 0.2]
Kujala score						
Cazatto et al[23]	SP (25)	NR	NR	85 (4)	NR	NA
Jones et al[10]	SP (36) vs. IP (38)	NR	NR	68 (23)	75 (19)	SMD 0.3 [−0.8 to 0.1]
Leliveld and Verhofstad[42]	IP (71)	NR	NR	NR	83 (16)	NA
Ozcan et al[27]	SP (21) vs. IP (37)	NR	NR	80 (9)	83 (8)	SMD -0.4 [−0.9 to 0.2]
Lysholm score						
Chan et al[12]	SP (11) vs. IP (14)	NR	NR	98	86	NA
Cazatto et al[23]	SP (25)	NR	NR	99 (7)	NR	NA
MacDonald et al[43]	SP (53) vs. IP (42)	93 (11)	84 (20)	NR	NR	SMD 0.6* [−0.2 to 1]
Ozcan et al[27]	SP (21) vs. IP (37)	NR	NR	85 (8)	83 (8)	SMD 0.3 [−0.3 to 0.8]
Sanders et al[14]	SP (36)	NR	NR	Excellent 14; good 8; fair 7; poor 8; * mean 82.2	NR	NA
HSS						
Cui et al[41]	SP (24) vs. IP (26)	NR	NR	97 (5)	97 (6)	SMD 0 [−0.5 to 0.5]
Fu[24]	SP (23)	NR	NR	92 (4)	NR	NA
OMAS						
Fu et al 2016[24]	SP (23)	NR	NR	94 (4)	NR	NA
Irrgang						
MacDonald et al[43]	SP (53) vs. IP (42)	Total 73 (8); symptoms 32 (4); function 41 (6)	Total 68 (13); symptoms 30 (7); function 38 (7)	NR	NR	SMD 0.5 [0.1 to 0.9]
QoL						
SF-36						
Cazatto et al[23]	SP (25)	NR	NR	79 (6)	NR	NA
Chan et al[12]	SP (11) vs. IP (14)	NR	NR	PCS 46 MCS 47	PCS 38 MCS 47	NA
Sanders et al[14]	SP (36)	NR	NR	PCS 42 MCS 48	NR	NA
SF-12						
Jones et al[10]	SP (36) vs. IP (38)	NR	NE	PCS 40 (13) MCS 49 (12)	PCS 43 (12) MCS 51 (9)	SMD -0.2 [−0.7 to 0.2] SMD 0.2 [−0.3 to 0.6]

IKDC (scale 0–100, 100 = no pain, no limitations in sports and daily activities), OKS (scale 0–48, 48 = no restrictions in terms of pain and function) Kujala Knee score (scale 0–100, 100 = excellent physical functioning) Lysholm Knee score (scale 0–100, 100 = no disability) HSS (scale 0–100, 100 = no discomfort) OMAS (scale 0–100, 100 = no symptoms and normal physical functioning) Irrgang (scale 0–80, 80 = no symptoms and excellent function) SF-36 (short-form 36), SF-12 (short-form 12), physical component scale (PCS), mental component scale (MCS).

*Excellent 95–100, good 84–94, fair 65–83, poor <65.

NR = not reported, NA = not applicable.

Does the SP- Versus IP-Technique Influence Complication Rates?

Another concern that may arise with SP-nailing is potential iatrogenic damage to intra-articular structures and cartilage as the nail passes the knee-joint.[2,3,34] Several cadaveric studies reported conflicting results.[13,15,47] Only Sanders et al[14] and Chan et al[12] reported on clinical evaluation of retropatellar chondropathy after SP-nailing with an average follow-up of 16 and 19 months, respectively. They found hardly any cartilage damage, gouges, or pressure changes from the SP-nail insertion cannula in the patellofemoral joint based on per-operative arthroscopy and MRI after 12-months. However, good-quality long-term data are limited, which may improve our understanding regarding this clinical concern.

The infection rates after the SP-approach and IP-approach were comparable and showed no relevant differences (12% vs. 9%). Most infections occurred after nailing of open fractures with comparable rates following SP or IP-nailing, indicating that open fractures are more decisive for infection instead of the nailing technique. The chance on developing knee sepsis after SP-nailing of open fractures was considerably low in comparison to IP-nailing.[16,17]

There is low evidence that SP-nailing leads to lower rates of malalignment. The current review showed significant differences in malalignment in the sagittal and coronal plane in favor of the SP-technique.[8–10] SP-nailing may be beneficial in facilitating reduction and obtaining accurate alignment in more proximal- and distal tibia fractures[14] as showed by Avilucea et al[8] who assessed distal tibia fractures. Fu et al[24] included proximal and distal tibia fractures, but all were treated with SP-nailing and no comparison to IP-nailing was made. It is noteworthy, however, that the absolute differences were small (reported SMD's ranged from −1.7 to 0.6 degrees) and therefore clinically irrelevant.[8–10] Moreover, radiographs were used to measure alignment, whereas CT-scans are superior in detecting malalignment.[13,38,39] The included studies in this review did not report on rotational malalignment based on CT-measurements. Low-dose CT-based data on rotational malalignment after SP-nailing is lacking and may be of added value to the ongoing debate on SP- or IP-nailing of tibial fractures as incidences up to 35% were reported after the IP-approach.[38,39]

Finally, this review illustrates that the SP-approach does not substantially decrease the complication rate in comparison to the traditional IP-approach in nonunion, subsequent surgeries and impaired ROM.

Does the SP- Versus IP-Approach Affect Physical Functioning and Quality of Life?

There is little evidence whether the SP-approach leads to superior physical functioning and QoL in comparison with the IP-approach. MacDonald et al[43] reported a significant difference between SP and IP-nailing using Lysholm scores after 12 months with an excellent score for the SP-group and good score for the IP-group (93 vs. 84). Overall, the recovery of physical functioning and QoL following SP and IP-nailing seems good. Although, 9 different outcome measures were used making is difficult to compare study results.

Strengths and Limitations

This systematic review contains strengths and limitations. This is the first review that encompassed the complete spectrum of outcome measures, including pain, complications, physical functioning, and general QoL after SP and IP-nailing. Second, search criteria were not limited by study design (eg, cohort study, RCT's), which provides a complete overview of all outcomes of interest published over the last decade. Third, this study provides a clinically question-driven overview about the ongoing debate on the nailing technique of tibial fractures.

Because of heterogeneity, inconsistent time-points, and a varying range of methodological quality, a pooled-analysis was not possible. However, results presented in this study were not subjected to any form of heterogeneity, and therefore validated and statistically reliable.

CONCLUSIONS

The SP and IP approach are both good techniques in tibial nailing with comparable results in anterior knee pain, complication rates (including retropatellar chondropathy, infection, and malalignment), physical functioning, and general QoL. The definitive choice should depend on the surgeon's experience and available resources.

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