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Review Article

A meta-analysis of suprapatellar versus infrapatellar intramedullary nailing for the treatment of tibial shaft fractures

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ABSTRACT

Background: Whether the optimal treatment for tibial shaft fractures is suprapatellar intramedullary nailing or infrapatellar approach is controversial.
Materials and methods: PubMed, Embase, Cochrane, Web of science and CNKI, Wan fang Chinese databases were retrieved from their establishment to April 26, 2017. Seven studies (three randomized and four clinical controlled trials) were included in the final analysis. This meta-analysis included 683 patients with tibial shaft fracture (suprapatellar: 341; infrapatellar: 342).
Results: There was significant difference between suprapatellar and infrapatellar approach surgery in the incidence of knee pain ($P = 0.003$). The malalignment of the sagittal and coronal plane in suprapatellar surgery was more serious than in the infrapatellar approach (sagittal plane: $P < 0.00001$; coronal plane:$P = 0.07$). The infrapatellar approach surgery was more time-consuming than suprapatellar surgery ($P = 0.01$), with no significant difference in knee function score ($P = 0.35$).
Conclusions: Suprapatellar intramedullary nailing reduced the incidence of knee pain and the average malalignment of fractures compared to infrapatellar intramedullary nailing. It also reduced the operation time and fluoroscopy time. The results of the study should be interpreted with caution due to the heterogeneity of the study designs.

1. Introduction

Tibial fractures are the most common long bone fracture in the human body [1]. There are a variety of treatment methods, such as Plate internal fixation and external fixation. Recently, intramedullary nailing has been considered the gold standard for the treatment of tibial shaft fractures [2], because it can provide good fracture reduction and early weight-bearing exercise. More importantly, intramedullary nail involves minimal surgical injury for preservation of blood supply to the fracture [3]. However, there are some disadvantages in traditional intramedullary nailing. With this method, the knee is in a flexed or hyperflexed position. This may lead to difficulty in the reduction and maintenance of proximal tibial fractures, and increase the risk of knee pain (incidence of 47% [4]. The cause of knee pain is multifactorial, possibly including stretching the tendon intra-operatively and injury to the infrapatellar nerve. Tornetta and Collins [5] introduced a semi-extended position of the knee during tibial nailing surgery for proximal tibial fractures. The suprapatellar approach uses an incision proximal to the patella, and the intramedullary nail passes through the trochlear groove. It carries no risk of damaging the patellar tendon and infrapatellar nerve, so it may reduce the rate of anterior knee pain [5]. This method helps to reduce varus and valgus deformities because the semi extended position may eliminate the extension force of the quadriceps [3]. The suprapatellar approach is controversial for it may lead to injury to the joint involvement and the cartilage. This analysis was conducted in order to determine whether the suprapatellar approach was safe, and to compare the suprapatellar with traditional infrapatellar approach in malalignment, anterior knee pain, and other complications.

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2. Main text

2.1. Materials and methods

2.1.1. Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) studies were randomized controlled trials or clinical controlled trials. (2) adult patients with tibial shaft fractures (including extra articular fracture of proximal and distal tibial). (3) suprapatellar nailing versus infrapatellarinfrapatellar nailing. (4) outcomes including complications, and/or function scores. The exclusion criteria were: (1) duplicated literature; (2) study of animals and cadavers.

2.1.2. Search strategy

A computer search was performed including PubMed, Embase, Cochrane, Web of science, and CNKI, Wan fang Chinese databases were retrieved from their establishment to April 26, 2017, without language restriction. The key terms for searching were: “tibia fractures” or “intramedullary approach” or “suprapatellar approach” or “infrapatellar nailing” or “retropatellar approach” or “Fixation, Intramedullary Fracture”.

2.1.3. Data extraction

The data of included studieswere extracted by two authors independently. The primary outcomes were anterior knee pain, malalignment, operation time and fluoroscopy time. Secondary outcomes included functional scores. Malalignment was defined as an angle of more than 5° or shortening of more than 1 cm.

2.1.4. Assessment of study quality

Two authors assessed the risk of bias for each included study. We evaluated randomized controlled trials based on the Cochrane risk bias tool [6]. Defined as low risk, unclear risk, or high risk. Methodological quality of nonRCT (controlled clinical trials) was assessed using the methodologic index for nonrandomized studies (MINORS Table 1) [7].

2.1.5. Statistical analysis

The statistical analysis was actualized using Review Manager (Version 5.3). Dichotomous data are revealed as risk ratios (RR), and continuous outcomes are presented as the weighted mean difference (WMD) or standard mean difference (SMD), both with 95% confidence intervals (CIs). Heterogeneity was determined to be significant at $I^2 > 50\%$ or $p < 0.1$. The random effects model was used when heterogeneity was significant, and a fixed effects model was used with homogeneity.

2.2. Results

2.2.1. Study selection and study quality

The selection flow is shown in Fig. 1. After preliminary screening, a total of 50 studies were selected (13 from PubMed, 8 from Embase, 1 from Cochrane library, 21 from Web of science, 6 from Wan fang and 1 from CNKI). After examining the studies carefully, 7 studies (2 from PubMed, 1 from Embase, 2 from Web of science, 1 from Wan fang, 1 from CNKI)were included in the final analysis (5 English studies and 2 Chinese studies) [8, 9, 10, 11, 12, 13, 14]. A total of 683 patients with tibial shaft fracture were included in this meta-analysis (suprapatellar:341; infrapatellar: 342). Three RCTs and CCTs (controlled clinical trials) were performed from 2014 to 2016. The range of the mean follow up was 6–24 months in the studies (8,9,11,12,14). Two studies did not state the follow up time (10,13). Percentage of patients who were followed up ranged from 61% to 100%. The characteristics of eligible studies was shown in Table 2.

The methodologic quality of the included RCTs is assessed in Fig. 2. Daniel S. Chan [8] generated randomized sequences by sealed envelopes. Sun Qi [9] conducted it by computer. One one study did not state the method of generation of random sequences. None of the patients in the RCTs were blinded to the surgical method. The outcome assessors were blinded in the study by Sun Qi [9], and not blinded in the study by Daniel S. Chan [8]. Liu Yang [13] did not discuss blinding. Four studies have missing data (8,9,11,12). All studies reported the reasons for the failure of the patients. All studies did not use selective reporting. The other sources of bias were unclear.

The MINORS scores of the retrospective studies are presented in Table 3. The limitations of the included studies are lack of blinding, prospective data collection and prospective calculations of the size of the study.

2.2.2. Primary and secondary outcomes of meta-analysis

There was significant homogeneity ($P > 0.05$, $I2 < 50\%$) among studies for the assessment of knee pain, sagittal plane alignment, operation time and Fluoroscopy time. Therefore, a fixed effects model was applied for them (Figs. 3, 4, 6, and 7) (see Figs. 5 and 8).

As shown in Fig. 3, there was significant difference between suprapatellar and infrapatellar approach surgery in the incidence of knee pain (RR,0.62; 95% CI,0.46to0.85, $P = 0.003$). The malalignment of the sagittal plane in suprapatellar surgery was more serious than in the infrapatellar approach (MD,-2.58; 95% CI,-2.80 to -2.37; $P < 0.00001$). Four studies reported the operation time. The infrapatellar approach surgery more time consuming than suprapatellar surgery (MD,-1.99; 95% CI,-3.56 to -0.41; $P = 0.01$). The fluoroscopy time during surgery of

Table 1
The items of MINORS.

Methodological items for non-randomized studies
1. **A clearly stated aim**: the question addressed should be precise and relevant in the light of available literature
2. **Inclusion of consecutive patients**: all patients potentially fit for inclusion (satisfying the criteria for inclusion) have been included in the study during the study period (no exclusion or details about the reasons for exclusion)
3. **Prospective collection of data**: data were collected according to a protocol established before the beginning of the study
4. **Endpoints appropriate to the aim of the study**: unambiguous explanation of the criteria used to evaluate the main outcome which should be in accordance with the question addressed by the study. Also, the endpoints should be assessed on an intention-to-treat basis.
5. **Unbiased assessment of the study endpoint**: blind evaluation of objective endpoints and double-blind evaluation of subjective endpoints. Otherwise the reasons for not blinding should be stated
6. **Follow-up period appropriate to the aim of the study**: the follow-up should be sufficiently long to allow the assessment of the main endpoint and possible adverse events
7. **Loss to follow up less than 5%**: all patients should be included in the follow up. Otherwise, the proportion lost to follow up should not exceed the proportion experiencing the major endpoint
8. **Prospective calculation of the study size**: information of the size of detectable difference of interest with a calculation of 95% confidence interval, according to the expected incidence of the outcome event, and information about the level for statistical significance and estimates of power when comparing the outcomes
(Additional criteria in the case of comparative study)
9. **An adequate control group**: having a gold standard diagnostic test or therapeutic intervention recognized as the optimal intervention according to the available published data
10. **Contemporary groups**: control and studied group should be managed during the same time period (no historical comparison)
11. **Baseline equivalence of groups**: the groups should be similar regarding the criteria other than the studied endpoints. Absence of confounding factors that could bias the interpretation of the results
12. **Adequate statistical analyses**: whether the statistics were in accordance with the type of study with calculation of confidence intervals or relative risk

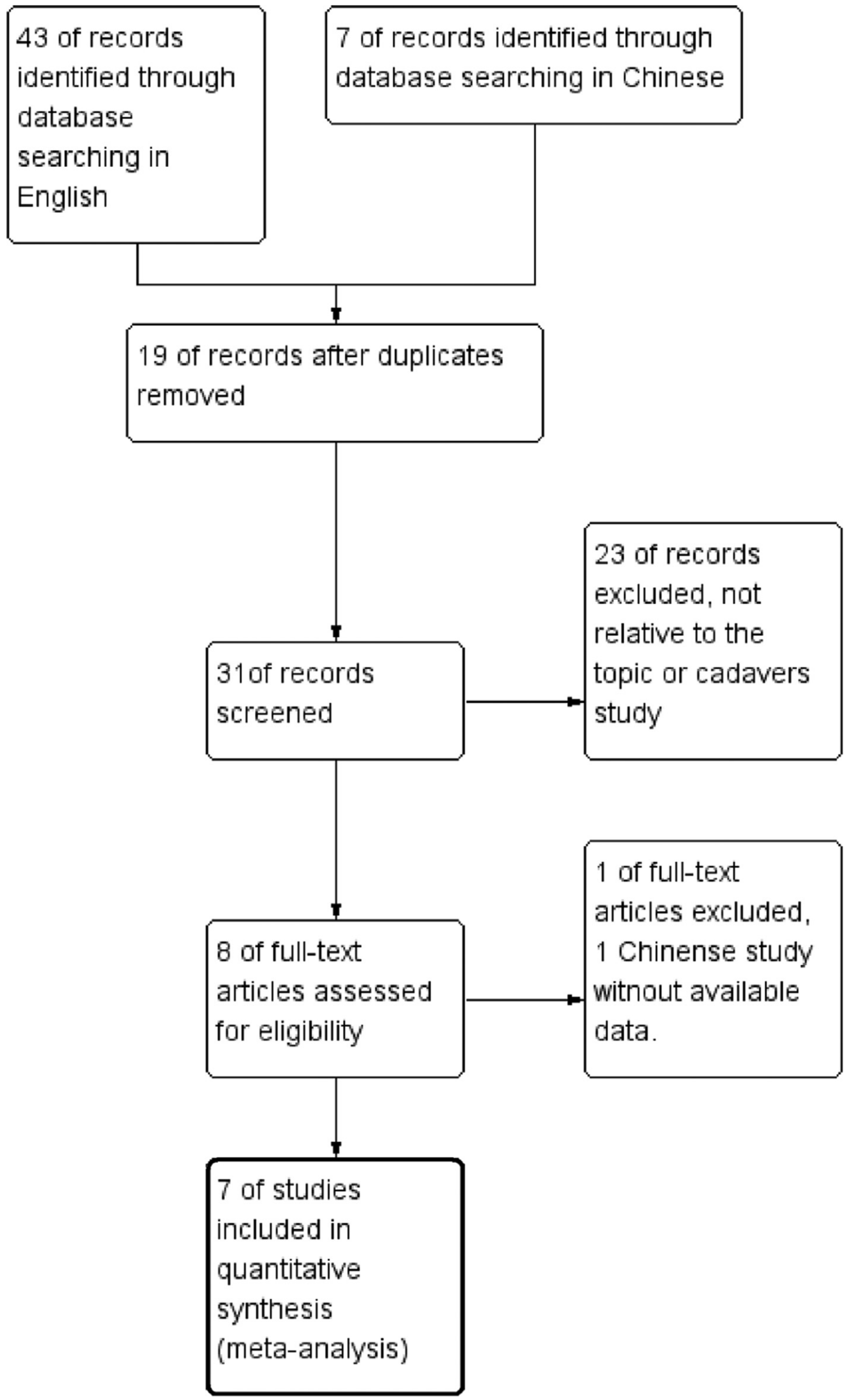

Fig. 1. Flow chart shows Article selection strategy.

suprapatellar approach was also shorter than in infrapatellar surgery (MD,-38.81; 95%,-49.74 to -27.87; $P < 0.00001$).

High heterogeneity ($I^2 = 89\%$,$I^2 = 92\%$) existed among studies that were available for the comparison of average coronal plane alignment and knee function score. Therefore, we applied the random effect model to analysis the data. The malalignment of the coronal plane in suprapatellar surgery was more serious than in infrapatellar approach surgery (MD,-1.66; 95% CI,-3.46 to 0.15; $P = 0.07$), but the knee function score of studies showed no significant difference (SMD,0.38; 95% CI,0.42 to 1.18; $P = 0.35$).

2.3. *Discussion*

Intramedullary nailing is considered the gold standard for the treatment of tibial shaft fractures [2], but there are some defects in traditional intramedullary nailing compared to infrapatellar, such as malalignment

Table 2
Characteristics of included studies.

study	design	NO.of patient		follow-up	withdrawals and dropouts	Jadad score
		SP	IP			
Qi Sun 2016	RCT	81	81	24 months	13. 8%	4
Daniel S.C 2016	RCT	23	18	15.5 months	16.39%	4
Liu yang 2016	RCT	28	28	not state	0	3
Frank 2016	CCT	132	134	not state	0	1
Mark 2014	CCT	36	38	23 months	15.20%	1
P.Maxwell 2015	CCT	21*	24*	11.8 months	37%	2
Wang 2016	CCT	38	30	6 months	0	1

RCT: randomized controlled trails, CCT:controlled clinical trials,SP:suprapatellar,IP:infrapatellar.
* The patients who were completed follow up.

and the incidence of knee pain. Tornetta and Collins [5] introduced a semi-extended position of the knee during tibial nailing surgery. Later, Jakma, Peter Reynders-Frederix and Rajmohan [15] developed a technique using a semi-extended position in which a small incision is made 1–2 centimeters proximal to the superior pole of the patella (suprapatellar approach). The skin incision is far away from the patellar

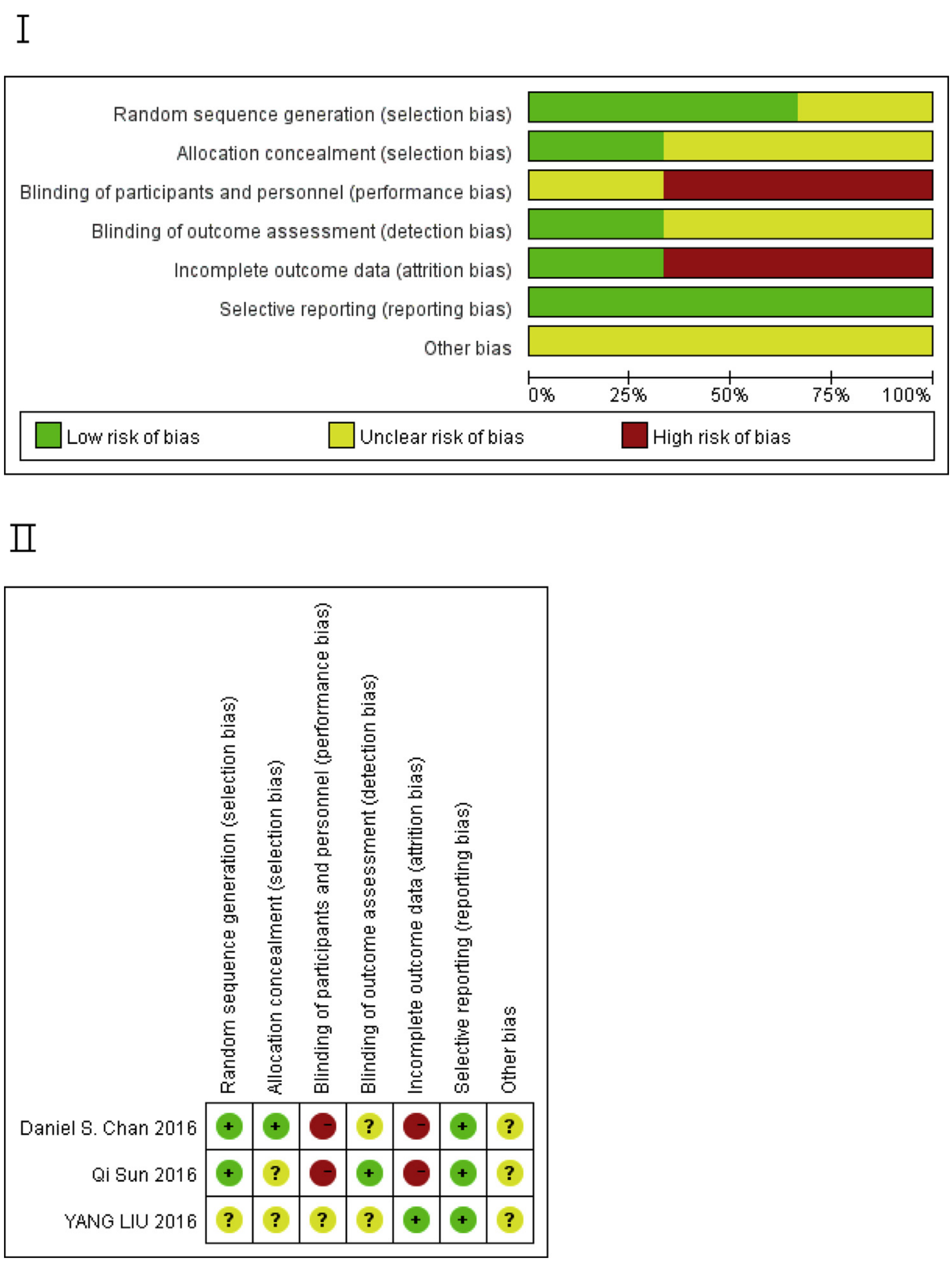

Fig. 2. Assessment of the risk of bias in the included RCT studies. I: Risk of bias graph; II: Risk of bias summary ("+": low risk of bias; "?": unclear risk of bias; "-": high risk of bias).

Table 3
MINORS scores for the included retrospective studies.

Study	MINORS ITEMS												total
	1	2	3	4	5	6	7	8	9	10	11	12	
Frank 2016	2	2	0	2	0	0	2	0	2	2	2	2	16
Mark 2014	2	2	0	2	0	2	0	0	2	2	2	2	16
P.Maxwell 2015	2	2	0	2	2	2	0	0	2	1	2	2	17
Wang 2016	2	2	0	2	0	2	2	0	2	2	2	2	18

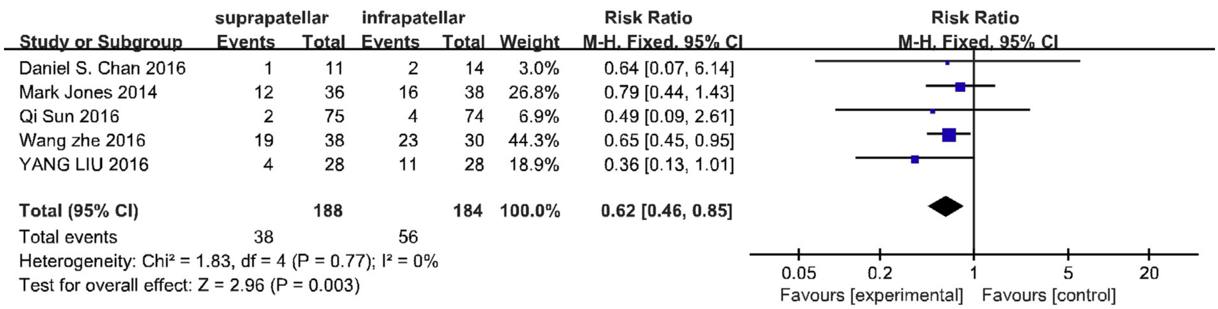

Fig. 3. Knee pain: suprapatellar vs infrapatellar.

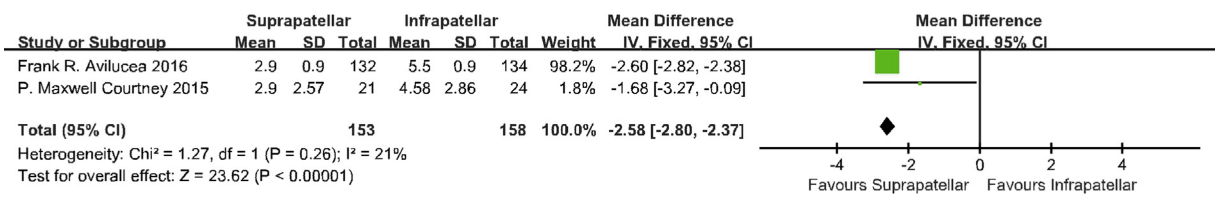

Fig. 4. Average sagittal plane alignment -suprapatellar vs infrapatellar.

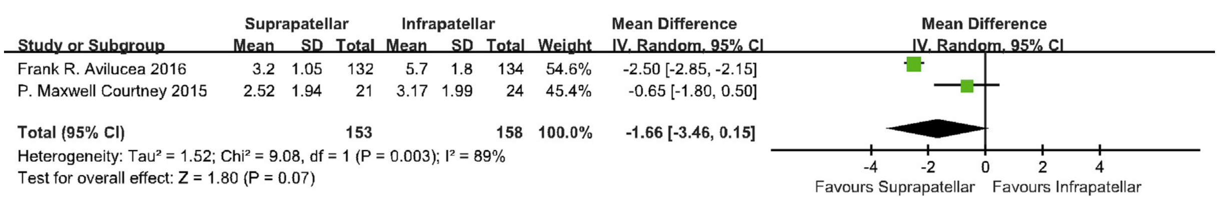

Fig. 5. Average coronal plane alignment - suprapatellar vs infrapatellar.

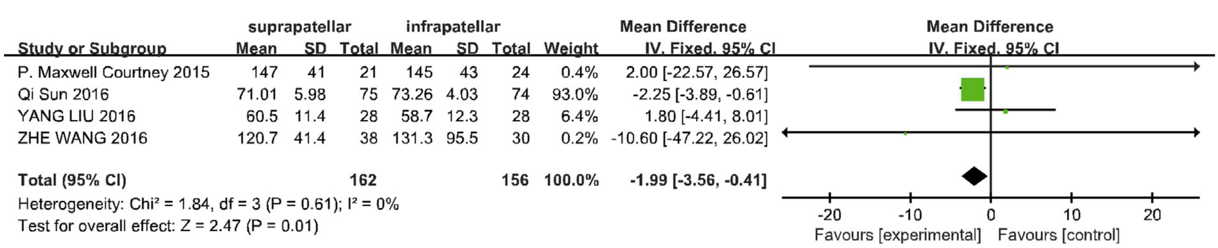

Fig. 6. Operation time - suprapatellar vs infrapatellar.

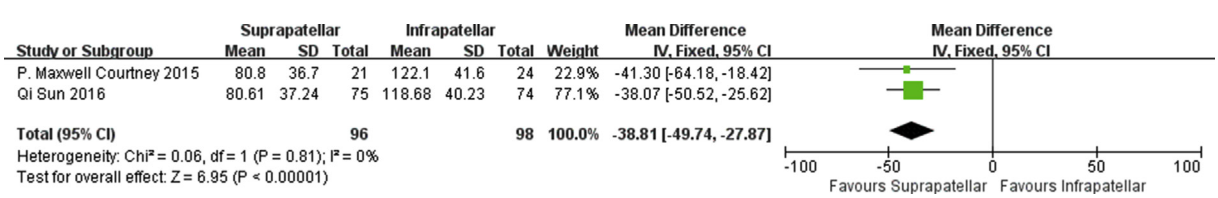

Fig. 7. Fluoroscopy time - suprapatellar vs infrapatellar.

tendon, thus avoiding additional trauma to the soft tissue that has been damaged. Moreover, the suprapatellar nail insertion has advantages in the reduction of the fracture in that it does not require hyperflexion of the knee to pass the nail, which may cause deformity of the fracture. Also, there is no risk of damaging the patellar tendon and the infrapatellar nerve, which can be involved inanterior knee pain. Frank [10] and

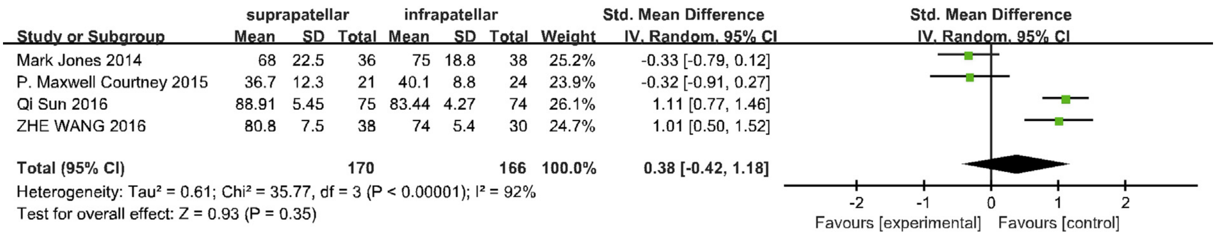

Fig. 8. Knee function score - suprapatellar vs infrapatellar.

colleagues point out that occurrence of angular malalignment in patients with infrapatellar IMN insertion was lower than in patients who underwent suprapatellar IMN insertion. They contend that the suprapatellar IMN technique enables significantly improved alignment of distal tibia fractures in both the coronal and sagittal planes. Additionally, the extended position of the lower leg allows for easier fluoroscopic imaging [8]. However, some surgeons argue that it will cause other problems such as knee sepsis [16] and injury of the knee structures [17]. Therefore, the meta-analysis was aimed at assessing the clinical efficacy of suprapatellar intramedullary nailing vs infrapatellar intramedullary nailing with regard toknee pain, malalignment, knee function scores, operation time, and fluoroscopy time.

Knee pain is a common complication of intramedullary nailing surgery. Although its etiology is unclear, it may be caused by injury to the knee structure and nerve. Eastman, .J.G and Tseng, .S.S [18] conducted a cadaveric study to assess whether the suprapatellar nailing insertion will injure the knee structure. They found that the intermeniscal ligament and medial meniscus were at greatest risk during suprapatellar IMN surgery, but the damage was within 1–2 mm. Leary, J et al [19], describes a novel percutaneous technique for the removal of a Suprapatellar IMN using the same instruments and incision used for nail insertion after the nail was inserted on the cadaveric specimen. They found no evidence of damage to any structures of the knee after the insertion and removal of the nail by suprapatellar approach. Courtney P. M [11] considers that the infrapatellar nerve is well protected in the suprapatellar approach. Their study showed no difference in knee pain scores between suprapatellar IMN and infrapatellar IMN, but Mark Jones [12] argues that the mean scores were higher in the infrapatellar group. Our meta-analysis agrees that there was a lower incidence of knee pain by suprapatellar approach compared to infrapatellar insertion.

Regarding malalignment, the meta-analysis revealed that both the average sagittal and coronal plane alignment in infrapatellar intramedullary nailing was signifiantly serious than suprapatellar that in intramedullary nailing. The infrapatellar nail insertion requires that the knee is hyperflexed to insert the intramedullary nail. Therefore, deforming muscle forces can cause proximal-third tibial fractures to fall into valgus and procurvatum [11]. The slight flexion is to neutralize the force of the extensor mechanism on the proximal tibia, leading to an apex anterior deformity, and to relax the tissues allowing for easier instrumentation in proper alignment [20]. When compared with an infrapatellar insertion, the suprapatellar approach is associated with a more accurate entry position and a more accurate fracture reduction [12]. Eastman, .J.G et al, [21] conducted a cadaveric study and point out that it is easier to achieve a satisfactory starting point and nail insertion angle by suprapatellar insertion.

Knee function scores and questionnaire reports from the related literature varied. Two studies used the Lysholm knee scale and SF-36 score, and the remaining two studies used the Kujala scale、SF-12 score, and Oxford knee score separately. High heterogeneity ($I^2 = 92\%$) existed among studies, probably caused by study design and randomization. Therefore, we used the random effects model to pool data. No significant difference was observed in the functional scores between the two approaches, but Daniel [8] discovered bodily pain of the SF-36 was worse in the infrapatellar group when compared with the suprapatellar cohort at 1 year postoperatively.

Fluoroscopy time and operation time was significantly shorter in suprapatellar insertion compared to infrapatellar. The semi extended position may facilitate the manipulation of the leg during the surgical procedure and the access of the fluoroscopic image intensifier [22]. That position may simplify the reduction of the fracture and ease efforts to maintain it during nailing [2]. Therefore, suprapatellar approach surgery will effectively reduce the operation time and fluoroscopy time when compared with infrapatellar insertion.

This is the first meta-analysis of suprapatellar versus infrapatellar IMN for the treatment of tibial shaft fractures. The analysis clearly had several limitations. Firstly, only three RCTs and 230 patients were included. The non-RCTs might influence the accuracy of the results. Secondly, The studies were small and lacked data regarding complications such as delayed union and nonunion. Thirdly, only 7 studies were eligible, so confounding bias and other selection bias may also exist. All of these may weaken the strength of evidence and clinical signifiance of the analysis. Thus, all conclusions should be interpreted with caution.

3. Conclusions

The results of our meta-analysis revealed that suprapatellar IMN reduces the incidence of knee pain and the average malalignment of fracture compared to infrapatellar IMN. It also reduces the operation time and fluoroscopy time. There was high heterogeneity among the studies. Thus, further research utilizing randomized control and large samples is warranted.

Declarations

Author contribution statement

Heng Xu: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Fushun Gu: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Jindang Xin: Contributed reagents, materials, analysis tools or data.

Chengguang Tian, Fei Chen: Performed the experiments.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

[1] C.M. Court-Brown, S. Rimmer, U. Prakash, M.M. McQueen, The epidemiology of open long bone fractures, Injury 29 (1998) 529–534.

[2] Ole Brink, Suprapatellar nailing of tibial fractures: surgical hints, Curr. Orthop. Pract. 27 (1) (2016) 107–112.

[3] Boris A. Zelle, Guilherme Boni, Safe surgical technique: intramedullary nail fixation of tibial shaft fractures, Patient Saf. Surg. 9 (40) (2015) 1–17.

[4] E. Katsoulis, C. Court-Brown, P.V. Giannoudis, Incidence and aetiology of anterior knee pain after intramedullary nailing of the femur and tibia, J. Bone Joint Surg. Br. 88 (2006) 576–580.

[5] P. Tornetta, E. Collins, Semiextended position of intramedullary nailing of the proximal tibia, Clin. Orthop. Relat. Res. 328 (1996) 185–189.

[6] J.P. Higgins, S. Green, Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 [Updated March 2011], The Cochrane Collaboration, 2011, http://www.cochrane.org/training/cochrane-handbook.

[7] K. Slim, E. Nini, D. Forestier, F. Kwiatkowski, Y. Panis, J. Chipponi, Methodological index for non-randomized studies (minors): development and validation of a new instrument, ANZ J. Surg. 73 (2003) 712–716.

[8] S.C. Daniel, S.R. Rafael, G. Rebecca, et al., Suprapatellar versus infrapatellar tibial nail insertion: a prospective randomized control pilot study, J. Orthop. Trauma 30 (3) (2016) 130–134.

[9] Q. Sun, X.Y. Nie, J.P. Gong, et al., The outcome comparison of the suprapatellar approach and infrapatellar approach for tibia intramedullary nailing, Int. Orthop. 40 (2016) 2611–2617.

[10] R.A. Frank, T. Kostas, S.W. Paul, et al., Suprapatellar intramedullary nail technique lowers rate of malalignment of distal tibia fractures, J. Orthop. Trauma 30 (10) (2016) 557–560.

[11] P.M. Courtney, B. Anthony, D. Derek, Functional knee outcomes in infrapatellar and suprapatellar tibial nailing: does approach matter? Am. J. Orthoped. 12 (2015) 513–516.

[12] Mark Jones, Michael Parry, W. Michael, Radiologic outcome and patient-reported function after intramedullary nailing: a comparison of the retropatellar and infrapatellar approach, J. Orthop. Trauma 28 (5) (2014) 256–262.

[13] Y. Liu, Clinical effect of intramedullary nailing via suprapatellar versus transpatellar tendon approach in the treatment of tibial shaft fracture, China Foreign Med. Treat. 6 (2016) 4–6.

[14] Z. Wang, S.L. Li, X.Y. Wang, Supra-patellar versus infra-patellar intramedullary nailing in treatment of tibial shaft fractures, Chin J orthop Trauma 18 (4) (2016) 283–289.

[15] Tijs jakma, Peter Reynders-Frederix, Rai Rajmohan, Insertion of intramedullary nails from the suprapatellar pouch for proximal tibial shaft fractures.A technical note, Acta Orthop. Belg. 77 (2011) 834–837.

[16] P.M. Mitchell, B.M. Weisenthal, C.A. Collinge, No incidence of postoperative knee sepsis with suprapatellar nailing of open tibia fractures, J. Orthop. Trauma 30 (2) (2016) 85–89.

[17] R.J. Gaines, J. Rockwood, J. Garland, et al., Comparison of insertional trauma between suprapatellar and infrapatellar portals for tibial nailing, Orthopedics 36 (9) (2013 Sep) e1155–e1158.

[18] J.G. Eastman, S.S. Tseng, et al., The retropatellar portal as an alternative site for tibial nail insertion: a cadaveric study, J. Orthop. Trauma 24 (11) (2010) 659–664.

[19] J. Leary, M. Werger, C. Sagebien, A novel technique for percutaneous removal of a suprapatellar intramedullary nail, Am. J. Orthoped. (2013; March) 136–140.

[20] D.J. Stinner, H. Mir, Techniques for intramedullary nailing of proximal tibia fractures, Orthop. Clin. N. Am. 45 (2014) 33–45.

[21] J.G. Eastman, S.S. Tseng, M.A. Lee, et al., The retropatellar portal as an alternative site for tibial nail insertion: a cadaveric study, J. Orthop. Trauma 24 (2010) 659–664.

[22] B.A. Zelle, G. Boni, Safe surgical technique: intramedullary nail fixation of tibial shaft fractures, Patient Saf. Surg. 9 (40) (2015) 1–17.