SYSTEMATIC REVIEW

Retrograde Intramedullary Nailing and Locked Plating for the Treatment of Periprosthetic Supracondylar Femur Fractures: A Meta-Analysis and Quantitative Review

Vishaal Sakthivelnathan, MD[1]; Prabhudev Prasad Purudappa, MBBS, MS[2]; Varatharaj Mounasamy, MBBS, MS[3]; Sujit Kumar Tripathy, MBBS, MS[4]; Akshay Goel, MBBS, MS[5]; Senthil Nathan Sambandam, MBBS, MS[3]

Research performed at the Veterans Affairs Medical Center, Boston and VAMC Dallas, USA

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Abstract

Background: As the prevalence of Total Knee Arthroplasty increases, there is still debate over the preferred method of treatment of supracondylar periprosthetic femoral fractures. The aim of this study was to compare two of the common methods of fixation: Locked Plating and Retrograde Intramedullary Nailing with respect to nonunion, delayed union and surgical revision rate.

Methods: A comprehensive database search via Pubmed was conducted, yielding 16 eligible studies. Six of those studies were comparative and were used in the meta-analysis section. All 16 studies were used in the pooled sample analysis section. The primary outcome analyzed was nonunion and delayed union rate while the secondary outcome was the surgical revision rate. Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated by comparing incidences of nonunion and delayed union, and surgical revision rates among the studies.

Results: The meta-analysis showed that there is no statistically significant difference among the two groups in terms of nonunion and delayed union rate (OR = 1.43, CI = 0.74, 2.74, *P=0.28*), but there is a significant difference in the surgical revision rate favoring locked plating over retrograde intramedullary nailing (OR = 2.71, CI = 1.42, 5.17, *P=0.003*). The pooled sample analysis showed that there is no significant difference in the nonunion and delayed union rates (*P=0.210*) or the surgical revision rates (*P=0.038*).

Conclusion: Both locked plating and Retrograde Intramedullary Nailing are reliable options for treating supracondylar femoral fractures around Total Knee Arthroplasty. Locked plating demonstrated a trend towards decreased nonunion and delayed union rates and a significantly lower surgical revision rate in the meta-analysis.

Level of evidence: IV

Keywords: Locked plating, Periprosthetic femoral fracture, Retrograde intramedullary nailing, Total Knee arthroplasty

Introduction

Total Knee Arthroplasty (TKA) is becoming an increasingly prevalent method to manage pain from osteoarthritis. The number of TKAs performed within the U.S. in 2012 was 700,100(1). A regression analysis conducted by Inacio et. al projects that this number will increase to 1.5 million cases a year in 2050 (2). Complications as a result of this procedure include periprosthetic fractures. The incidence of periprosthetic supracondylar femoral fractures in patients who had TKA has been estimated to be between 0.3%-2.5%(3,4) and this is also projected to increase because of the projected increase in the number of TKA and increased life expectancy.

Internal fixation of the displaced supracondylar

Corresponding Author: Vishaal Sakthivelnathan, UTMB School of Medicine, TX, USA
Email: prabhudevprasad@gmail.com

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periprosthetic femur fractures in the presence of a stable knee prosthesis is the recommended treatment option to achieve stability and alignment to facilitate early mobilization of the patient (5). Surgical treatment of these fractures is challenging because of short distal fragment, osteoporotic bone in elderly patients with multiple comorbidities (5, 6). Locked plating and retrograde intramedullary nailing (RIMN) are the two most commonly used surgical treatment options (5). Locked plating offers biomechanical advantages with friction reduction, even distribution of load across multiple screws, fixed angle construct and stable fixation in osteoporotic bone (5, 7). RIMN has the potential advantages of load sharing, less invasive surgery, minimal soft tissue stripping, lower risk for nonunion and revision surgery (8, 9). However, there is no clear consensus among the preferred method between locked plating and RIMN. Matlovich et al reported no statistical difference between the two groups in the meantime taken to fully weight bear, the incidence of postoperative pain, range of motion, use of gait aids, time to full radiographic union, or the overall radiographic alignment of a healed fracture (10). Meneghini et al in their study reported that the failure rate of locked plating was twice that of RIMN fixation with 9% nonunions in the RIMN group and 19% nonunions/delayed-unions in the locked plate group (11). It appears from the literature that the incidence of nonunion/delayed union and revision surgery rates are among the most important complications driving the decision in the selection of these two methods of fixation. In order to address this question, we conducted a review of the available literature.

The aim of this systematic review was to study the nonunion, delayed union and revision surgery rates associated with locked plating and RIMN through a pooled sample analysis, and to perform a meta-analysis on a set of comparative studies.

Materials and Methods

The study was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and followed the Cochrane review method. Two investigators independently searched the PUBMED database from dates January 1st 2000 to August 31st 2020 to identify the studies which evaluated the treatment of periprosthetic supracondylar femur fractures around a total knee arthroplasty using RIMN and locked plating [Figure 1]. The following keywords and their various combination and the relevant Medical Subject Headings (MeSH) were used to find the relevant articles: 'periprosthetic fractures OR total knee arthroplasty' OR 'supracondylar femur fracture' OR 'retrograde intramedullary nail' OR 'locked plating'. After the initial search of the electronic database, the references of the relevant articles were manually searched to find additional studies. Only studies published in the English language were included in this study. No institutional review board approval or informed consent was needed because this was a review of the already published literature.

Studies evaluating the clinical outcomes of locked plating and RIMN in the treatment of periprosthetic supracondylar femur fractures around TKA with at least 1 year of follow up were considered for inclusion. Case reports, cadaveric studies, review articles and letters to the editors were excluded. A total of 841 articles were retrieved. After reviewing the summaries of the texts, 106 articles written in English were marked for abstract review. Relevant studies were selected by two reviewers independently after screening through the titles and abstracts and the final decision to include the screened studies in the review was confirmed by full text review. Any disagreements during this process were resolved by consensus opinion between the two reviewers or by consulting with a third investigator. A total of 16 studies were included, all 16 were used in the pooled sample analysis, and only 6 comparative studies were used for the meta-analysis. The data from each study was independently recorded by two reviewers using data extraction form and any differences were later resolved by consultation with one another. Following data was extracted from the studies; first author, year

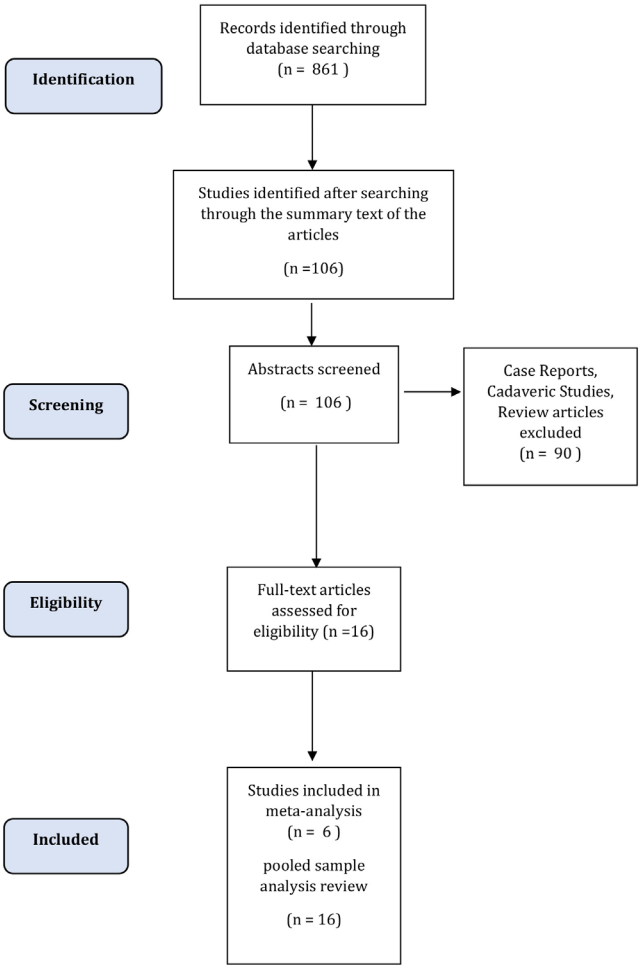

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow chart.

Table 1. Locked plating group characteristics

Author, year	Sample Size	Age	BMI	History of Smoking	Fracture Type	Non-union Events	Non-union Rate	Delayed Union Events	Delayed union rates	Nonunion + Delayed Union Rate	Average Time to Union (months)	Total Complication Rate	Number of Revisions	Surgical Revision Rate
Ebraheim, 2012	27	75.07	NR	NR	NR	1	3.70%	2	7.40%	11.11%	4.5	37%	7	26%
Eschbach, 2018	37	76	NR	NR	Rorabeck 1 or 2	2	5.41%	0	0	5.41%	NR	NR	8	22%
Hoffmann, 2012	36	73.2	32.4	14%	Rorabeck 1 or 2	8	22.22%	0	0	22.22%	NR	25.70%	12	33.30%
Large, 2008	25	74.8	NR	NR	Rorabeck 2	0	0.00%	0	0	0.00%	NR	NR	3	12%
Gavaskar, 2013	19	73	NR	NR	Rorabeck 1 or 2	1	5.26%	2	10.50%	15.79%	5.5	26.32%	1	5.26%
Horneff, 2013	28	68.3	28.4	NR	NR	2	7.14%	0	0	7.14%	4.86	NR	4	14.29%
Hoellwarth, 2018	87	80	32.6	5.75%	OTA-33	1	1.15%	0	0	1.15%	NR	NR	9	10.37%
Lotzien, 2018	45	74	27.4	NR	OTA-33	2	4.44%	6	13.30%	17.74%	NR	NR	10	22%
Bae, 2013	14	67	26.3	NR	NR	1	7.14%	0	0	7.14%	4.2	7.14%	1	7.14%
Meneghini, 2014	63	74	NR	3%	OTA-33	NR	19.05%	0	0	19.05%	NR	NR	6	9.52%
Matlovich, 2017	36	76	NR	NR	OTA-33	0	0.00%	0	0	0%	NR	NR	1	2.70%
Gondalia, 2014	24	67.2	NR	NR	OTA-33	7	29.17%	0	0	29.17%	11.1	29.20%	4	16.70%
Hou, 2011	34	75	NR	NR	OTA-33	3	8.82%	0	0	8.82%	4	20.60%	2	5.88%

NR = Not Reported

of publication, sample size, average age, BMI, smoking history, fracture type, nonunion events, nonunion rate, delayed union events, delayed union rate, average time to union, total complication rate, number of revisions, surgical revision rate [Table 1; 2]. The primary outcome analyzed in this study was the rate of nonunion and delayed union while the secondary outcome was the surgical revision rate.

Quality Assessment

Two investigators independently performed the quality assessment using the Modified Coleman Methodology score, which has a maximum score of 100 [Table 3]. The scoring system consists of Part A and Part B. Part A has seven criteria with one score given to each section and Part B has 3 criteria with scores given for each option in each of the 3 sections if applicable [Table 3].

Statistical Analysis

The meta-analysis on the nonunion and delayed union rate and the surgical revision rate was conducted between the Locked Plating and RIMN groups. A fixed effect model was used for both outcomes. The Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated by comparing incidences of nonunion and delayed union, and surgical revision rates among the studies. Heterogeneity was assessed using the $I2$ statistic, $I2$ of 25% was regarded as low heterogeneity, 50% was regarded as moderate heterogeneity, and 75% was regarded as high heterogeneity. Review Manager 5.4 was used for the meta-analysis, and IBM SPSS was used for the pooled sample analysis.

Table 2. Retrograde intramedullary nail group characteristics

Author, year	Sample Size	Age	BMI	History of Smoking	Fracture Type	Non-union Events	Non-union Rate	Delayed Union Events	Delayed union rates	Nonunion + Delayed Union Rate	Average Time to Union (months)	Total Complication Rate	Number of Revisions	Surgical Revision Rate
Gliatis, 2005	10	69.6	NR	NR	NR	0	0%	1	10%	0%	3%	10%	1	10%
Han, 2008	8	68	NR	NR	NR	0	0%	0	0	0%	3.25	0%	0	0%
Lee, 2013	25	71	NR	NR	OTA-33	0	0%	0	0	0%	3	16%	1	4%
Meneghini, 2014	22	74	NR	22%	OTA-33	2	9.09%	0	0	9.09%	NR	NR	1	4.55%
Matlovich, 2016	19	75	NR	NR	OTA-33	2	10.53%	0	0	10.53%	NR	NR	5	26.3%
Gondalia, 2014	18	67.2	NR	NR	OTA-33	3	16.67%	0	0	16.67%	9.6	27.80%	3	16.70%
Hou, 2011	18	77	NR	NR	OTA-33	1	5.56%	2	11.11%	16.67%	3.7	16.70%	2	11.11%
Large, 2008	7	74.1	NR	NR	Rora-beck 2	3	42.86%	0	0.00%	42.86%	NR	NR	0	57.14%
Horneff, 2013	35	69.5	31.3	NR	NR	8	22.86%	0	0	0%	4.26	14%	14	40%

NR - Not reported

Table 3. Modified Coleman methodology score of the included studies

Studies	Study size	Mean duration of follow-up	Number of surgical procedures	Type of study	Diagnostic certainty	Description of surgical procedure	Description of postoperative rehabilitation	Outcome measurements	Outcome assessment	Selection process	Total score
Ebraheim 2012	7	0	10	10	0	5	0	0	0	0	32
Eschbach 2018	7	2	10	10	0	5	0	0	0	0	34
Hoffmann 2012	7	0	10	0	0	5	0	0	0	0	22
Large 2008	7	2	10	0	0	0	0	0	0	0	19
Gavaskar 2013	0	5	10	0	0	0	0	0	0	0	15
Horneff 2013	10	5	10	0	0	0	0	0	0	0	25
Hoellwarth 2018	10	2	10	0	0	0	0	0	0	0	22
Lotzien 2018	7	5	10	0	0	0	0	0	0	0	22
Bae 2013	0	2	10	0	0	0	0	0	0	0	12
Meneghini 2014	10	0	10	0	0	0	0	0	0	0	20
Matlovich 2016	7	2	10	0	0	0	0	0	0	0	19
Hou 2011	7	5	10	0	0	0	0	0	0	0	22
Gliatis 2004	0	5	10	10	0	5	10	0	0	0	40
Han 2008	0	5	10	10	0	5	0	0	0	0	30
Lee 2013	0	5	10	0	0	0	0	0	0	0	15

Results

Study Characteristics

Two of the studies (12,13) included were prospective non-randomized trials, and fourteen studies (5,9–11,14–23) were retrospective non-randomized studies. Six studies (10,11,15,19–21) were comparative studies that were

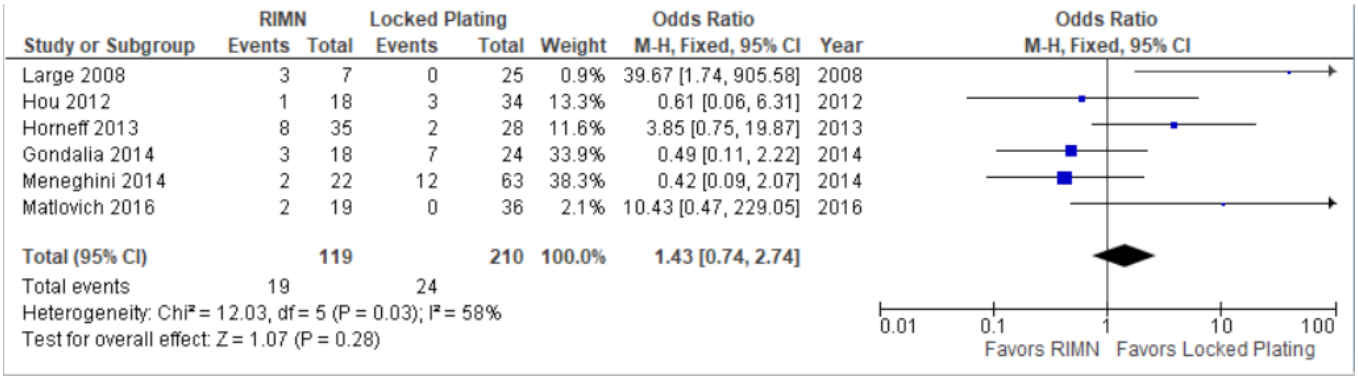

Figure 2. Meta-Analysis of Nonunion and Delayed Union Rates.

included in the meta-analysis as well as the pooled sample analysis. Ten studies(5,9,10,12–14,16–18,22) were single-arm studies that were only included in the pooled sample analysis. The mean Coleman Methodology Score was 47.94%. The articles are level III evidence.

Meta-Analysis

Six studies, with a total of 333 fractures, were included within the meta-analysis. Individual ORs and CIs as well as an overall OR and CI were calculated. The odds of the nonunion and delayed union rate were slightly higher in the RIMN group (1.4 with a CI 0.74 to 2.74). However, there was no statistically significant difference in the overall nonunion and delayed union rate with respect to the two methods of fixation (*P=0.28*) [Figure 2]. There was a statistically significant difference in the surgical revision rate, favoring locked plating over RIMN (*P=0.003*) [Figure 3].

The heterogeneity under the fixed effects model was moderate for the surgical revision rate (Heterogeneity: $Chi^2 = 7.99$, df = 5 (*P = 0.16*); $I^2 = 37\%$). The heterogeneity under the fixed model was high heterogeneity (Heterogeneity: $Chi^2 = 12.03$, df = 5 (*P = 0.03*); $I^2=58\%$). As a result, we ran a random effects model for the two groups comparing the nonunion and delayed union rates. This model indicated no statistical difference in the overall nonunion and delayed union rate among the two groups (*P=0.42*).

Pooled sample analysis

Demographics

A total of 22 cohorts (13 locked plating cohorts and 9 RIMN cohorts) were included for this part of the study from the 6 comparative and 10 non-comparative studies. A total of 475 patients underwent locked plating and a total of 162 patients underwent RIMN. The average age was not statistically significant between both groups (73.35 in the locked plating group and 71.71 in the RIMN group). BMI was reported in six studies and was not statistically significant. Other factors, such as smoking and osteoporosis, known to increase fracture-related complications were reported in 2 RIMN studies and 6 locked plating studies but there was no statistical significance for either variable between the groups.

Nonunion and delayed union rate

The locked plating studies reported a total of 38 nonunions and delayed unions at a rate of 8%. The RIMN studies reported a total of 19 nonunions at a rate of 11.73%. The difference in nonunion and delayed union rate among RIMN and locked plating was not statistically significant (*P=0.210*).

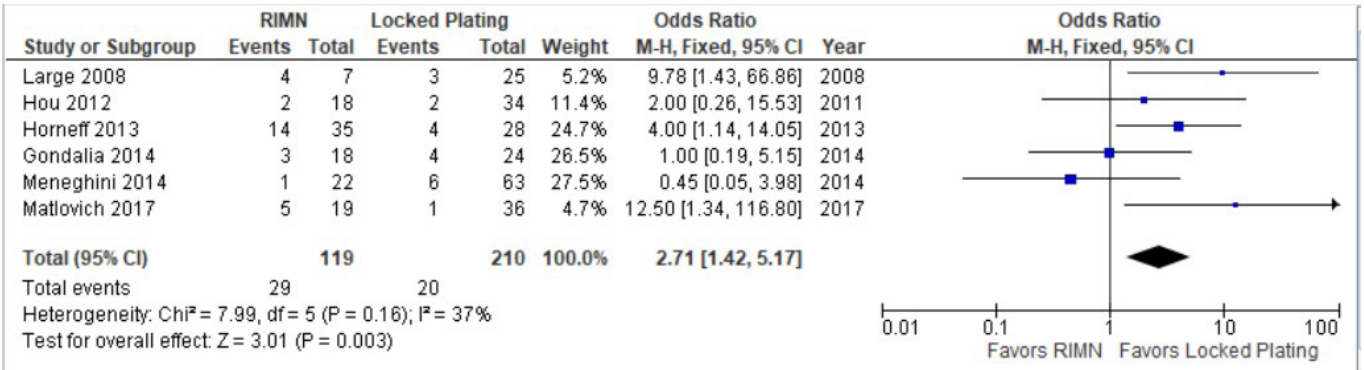

Figure 3. Meta-Analysis of Surgical Revision Rates.

Revision rates

The locked plating studies reported a total of 64 revision surgeries at a rate of 13.47 %. The RIMN studies reported a total of 24 nonunions at a rate of 14.81%. There was no significant difference in the surgical revision rate (*P=0.469*). Levene's test for equality of variances indicates that the spread of the surgical revision rate in the RIMN study data was greater than that of the locked plating data (*P=0.038*), suggesting higher variability in the clinical outcome is more likely to occur with RIMN than locked plating.

Discussion

Retrograde intramedullary nailing and open reduction internal fixation (ORIF) with lateral locked plating are currently the most common procedures for the treatment of displaced supracondylar femur fractures with well-fixed prosthetic knee implants were collected and categorized into fracture type and treatment method groupings (24). Healing outcome and complications were the two parameters used to analyze the data. Treatment techniques were grouped in the following categories: locking plate, non-locking plate, intramedullary nail/rod, screw, blade plate, cerclage wires, allograft, external fixation, revision arthroplasty, non-operative, and other. Classification systems by Lewis and Rorabeck, the Association for Osteosynthesis/Orthopedic Trauma Association (AO/OTA. But there is also lack of information to guide the surgeons toward a particular fixation technique according to the union rates and revision surgery rates. Our metanalysis shows that both locked plating and RIMN are reliable options for the management of periprosthetic femoral fracture around total knee replacement. Both the meta-analysis and the pooled sample analysis showed that there is no significant difference in the nonunion rate and delayed union rate between the two treatment modalities. The metanalysis demonstrated a higher revision surgical rate with RIMN as compared to locked plating.

Several authors have reported satisfactory outcomes with RIMN. Gliatis and Han et al in a series of 9 patients each and Lee et al in a series of 25 patients reported 100% union rates with RIMN (9, 16, 22). One patient in the series of Gliatis et al needed revision to a stemmed total knee arthroplasty due to severe valgus malunion (9). Lee et al reported one revision surgery under local anesthesia for removal of a broken distal interlocking screw (22).

In a recent study Lotzien et al retrospectively evaluated 45 patients of periprosthetic supracondylar femoral fractures with well-fixed knee prosthesis treated with polyaxial locking plates. 35 of the 45(78%) fractures healed within 6 months after the index procedure (23). Revision surgery was performed in 10 (22%) patients due to various reasons including non-union, delayed union and infection. Their group had a 26.7% mortality, with 12 patients in the study group deceased during the study period. Their data with high reoperation rates and high post-operative mortality demonstrates that the management of these fractures is challenging irrespective of the method of fixation. Gavaskar et al(14) achieved successful union in 18 of the 19 patients treated with locked plates. They reported six secondary procedures in 5 (26%) patients, autologous iliac crest grafting in 3 patients; revision arthroplasty in 1 patient and knee manipulation under anesthesia in 2 patients. Aldrian et al in a retrospective study comparing the fixation of supracondylar femoral fractures following total knee arthroplasty reported union rates of 85.4% within the locked plate group by using an angular stable plate system (25).

Meneghini et al reported one of the largest series of periprosthetic fracture fixation published to date and they included 63 patients who underwent locked plating and 22 who underwent RIMN (11). Their study showed union-related complications in 12(19%) out of 63 patients in the plating group compared to 2(9%) out of 22 patients in the RIMN group. The average time to union was 16 weeks. This study showed favorable odds for RIMN (0.42, CI 0.09 to 2.07). However, this contrasts with the findings of this metanalysis, further validating the strength of the meta-analysis and the pooled sample analysis, neither of which showed any statistically significant difference favoring nailing over plating. Further evaluation of the Meneghini et al study revealed nearly double the number of patients with RIMN as compared to any of the studies included in the metanalysis (11). Hence, the better outcome reported by Meneghini et al might be related to the clinical experience gained by doing more nailing, leading to the plausible hypothesis that higher volume periprosthetic fracture surgeons who routinely use both plates and nails are more likely to have better results with nailing (11). However, this hypothesis would require a comparative study with larger number of patients in the future to prove or disprove it. They also reported a possible surgeon bias in selecting RIMN for patients with lower ambulatory status, in spite of this the RIMN group demonstrated a failure rate 50% less than the locked periarticular plate group.

In a comparative study by Matlovich et al(10) no statistical difference was found in the meantime to fully weight bear between locked plate fixation and RIMN, the range of motion was also comparable, with the locked plating group achieving 2.50 ± 6.70 of extension and 102.90 ± 11.00 of flexion and the RIMN nail cohort achieving 0.30 ± 1.20 extension and 101.80 ± 16.70 flexion. They didn't find any difference in the radiological time to union, alignment in the sagittal and coronal planes was also similar between the two groups. They found a significantly higher reoperation rate of 26.3% in the RIMN group as compared to 2.7% in the locked plate group, this is in agreement with our finding in the meta-analysis.

Surgical revision is another factor analyzed in our study. The pooled sample analysis showed no statistical difference between the two groups; however, there is a trend toward higher variability with the results of the RIMN group. The meta-analysis showed clearly that the surgical revision rate is higher in the RIMN group compared to the locked plating group, further reiterating

that the comparative studies and rigorous statistical tests are often needed to answer any clinical questions.

There are several limitations in this study. Ten of the sixteen studies were single arm, and none of the studies were randomized controlled trials. The results should be assessed with caution as a result of the nonrandomization aspect of the studies and possible selection bias. All but two of the studies were retrospective. A difference in the variable definition of delayed union had to be resolved. Gavaskar et al defined delayed union as lack of satisfactory healing by the 4th month while the other studies used the 6th month (14). This study evaluated only the nonunion, delayed union and revision surgery rates between the two techniques. We didn't analyze the various reasons for revision surgeries, differences in the functional outcomes between the two techniques and other perioperative complications.

Both locked plating and Retrograde Intramedullary Nailing are reliable options for treating supracondylar femoral fractures around Total Knee Arthroplasty. Locked plating demonstrated a trend towards decreased nonunion and delayed union rates and a significantly lower surgical revision rate in the meta-analysis. As the pool sample analysis did not result in the same statistically significant lower surgical revision rate, more comparative studies are needed to get a more accurate understanding.

Authors' contributions: VS and PP did the initial literature search, VM and SS independently performed the quality assessment using the Coleman Methodology criteria. VS, PP and ST did the data collection, statistical analysis and preparation of the manuscript. All authors read and approved the final manuscript.

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Vishaal Sakthivelnathan MD[1]
Prabhudev Prasad Purudappa MBBS MS[2]
Varatharaj Mounasamy MBBS MS[3]
Sujit Kumar Tripathy MBBS MS[4]
Akshay Goel MBBS MS[5]
Senthil Nathan Sambandam MBBS MS[3]
1 UTMB School of Medicine, TX, USA
2 Boston VA Medical center, Boston, MA, USA
3 Dallas VA Medical Center, Dallas, TX, USA
4 AIIMS, Bhubaneswar, India
5 Marshall Health, Huntington, USA

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