Plating fixation or ring fixation compression during a masquelet technique for tibial fracture patients: a systematic review and meta-analysis

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Purpose
The purpose of this study is to compare the outcomes of using a ring fixator compression or plating fixation in tibial shaft fracture patients treated with the Masquelet technique.
Methods
The author conducted a search of the literature for studies that compared the use of a ring fixator or plate for the Masquelet technique in patients with tibial shaft fractures. All full English only articles in the form of randomized and nonrandomized studies were included. Search engines used included PubMed/Medline, Scopus, Cochrane, Web of Science, Embase, Google scholar, Science Direct, and Clinicaltrials.gov.
Results
The results demonstrate that, patients who underwent the plating fixation with Masquelet technique had greater risks of developing superficial surgical site infections ($P < 0.001$), stiffness/decreased range of motion ($P < 0.001$), wound and soft tissue disclosure ($P = 0.026$), postoperative fractures ($P < 0.001$), and had overall greater risk for postoperative failure ($P = 0.003$) in comparison to the ring fixation compression with Masquelet technique. In terms of deep surgical site infections, there was no significant difference between the two techniques. The results of this study would therefore suggest that the ring fixation compression with Masquelet technique is a greater alternative to the plating fixation with Masquelet technique for tibial shaft fracture patients.
Conclusion
Plating fixation with Masquelet technique had significantly higher rates of superficial surgical site infection, operation failure, refracture, stiffness with decreased range of motion, wound and soft tissue disclosure than ring fixation compression. This would suggest that ring fixation compression with Masquelet technique is a better alternative to repairing tibial fractures than plating fixation with Masquelet technique.

Keywords:
masquelet technique, plating fixation, ring fixation, tibial fractures

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Introduction

Compared with most long bone fractures, tibial shaft fractures are more likely to be open because the medial surface is adjacent to the subcutaneous tissue [1,2]. Operative management of bone fractures aims at stabilizing, restoring length, realigning, and preserving optimal function of the affected bone. Two of the operative techniques that we will be analyzing in this systematic review and meta-analysis include the plating and ring fixation of the Masquelet technique.

Plating is technically difficult in situations with bone loss, which may require extensive exposure, particularly if there is a segmental defect to bridge. Plating is biomechanically unfavorable in the presence of a defect due to cantilever loading. Novel plate designs have been built and may have an advantage over conventional plates, but still require more research to determine their effectiveness [3]. A plate spanning a segmental defect will prevent the use of distraction osteogenesis or segmental bone transport. Therefore, plates are rarely the treatment of choice in diaphyseal fractures with bone loss but continue to be useful for metaphyseal and articular defects where other methods of fixation may not be as readily applied [4].

External fixation is a versatile method of treating fractures with bone loss. Modern frames have multiple advantages. Circular frames, for example, are useful for

extensive defects, particularly if distraction osteogenesis is being planned, or if there is an additional deformity requiring correction [5]. Other advantages of external fixation frames include its use in any location, it can be used for short juxta-articular fractures, it can lengthen and transport bone, it is used to correct deformities, and utilized for lower limbs in conjunction with intramedullary nailing [5]. The drawbacks of using external fixation include the long-term use of the frame, septic arthritis, increased risk of malunion, decreased compliance with extended use, and pin-track infections that may require additional treatment [6].

The Masquelet technique uses a temporary spacer followed by bone grafting in order to repair large areas of defective bone, typically in patients with posttraumatic bone defects or surgical debridement as a result of infection, nonunion, joint fusion, tumor, or congenital pseudarthrosis [7]. The temporary spacer uses various types of cement, which studies have proven beneficial in the healing of long bone defects, and the type of cement used has no significant influence on the formation of new bone [4,6–8]. As for the bone grafting, the volume of graft should be adequate to cover the whole defect, but should not be too excessive as to prevent closure of the membrane [7,9,10]. Studies have demonstrated positive outcomes of using the Masquelet technique. Complications of this technique include nonunion, fracture, lysis of the graft, and infection. Contraindications include bone defects that involve joints, osteomyelitis, chronic infection, insufficient soft tissue coverage, and osteoporosis [1,3].

The purpose of this systematic review and meta-analysis is to thoroughly investigate all literature that compared the outcomes of using a ring fixator or plating in tibial shaft fracture patients treated with the Masquelet technique. Outcomes individually analyzed in the selected studies included; surgical site infection (deep and superficial), postoperative failure, risk of refracture, risk of developing stiffness and decreased range of motion (ROM), as well as wound/soft tissue disclosure.

Methods

This systematic review meta-analysis is registered by PROSPERO [ID: CRD42022342664].

Search strategy

We performed an extensive electronic search using the following search engines; PubMed/Medline, Scopus, Cochrane, Web of Science, Embase, Google Scholar, Science Direct, and Clinicaltrials.gov. Keywords used in the search included Masquelet Technique, Plating Fixation, Ring Fixation Compression, and Tibial shaft Fractures.

Types of studies

Studies included were single or double armed studies in the form of randomized controlled trials, prospective cohort, retrospective cohort, case controlled, and case series.

Types of intervention/patient selection

Any article which compared the use of plating fixation or ring fixator compression during the Masquelet repair for tibial fracture was included in this review.

Inclusion criteria

All full English only published articles/studies were included in this systematic review. Initial screening was performed using the titles and abstracts, and any duplicates were removed. In case of missing data, authors of the articles were contacted to provide further details when necessary. Reference lists of the included studies were manually screened to find any other eligible studies that may be omitted from previous steps. This systematic review and meta-analysis was conducted in accordance with PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines (Fig. 1) and the Cochrane handbook for systematic reviews of intervention.

Exclusion criteria

All nonEnglish articles, grey articles, conference papers, or unpublished/preprint manuscripts were not included in the study. Studies that included fracture repair techniques that were not associated with plating/ring fixation of the Masquelet technique were excluded. Any study that had not included the outcomes assessed in this study was also not included.

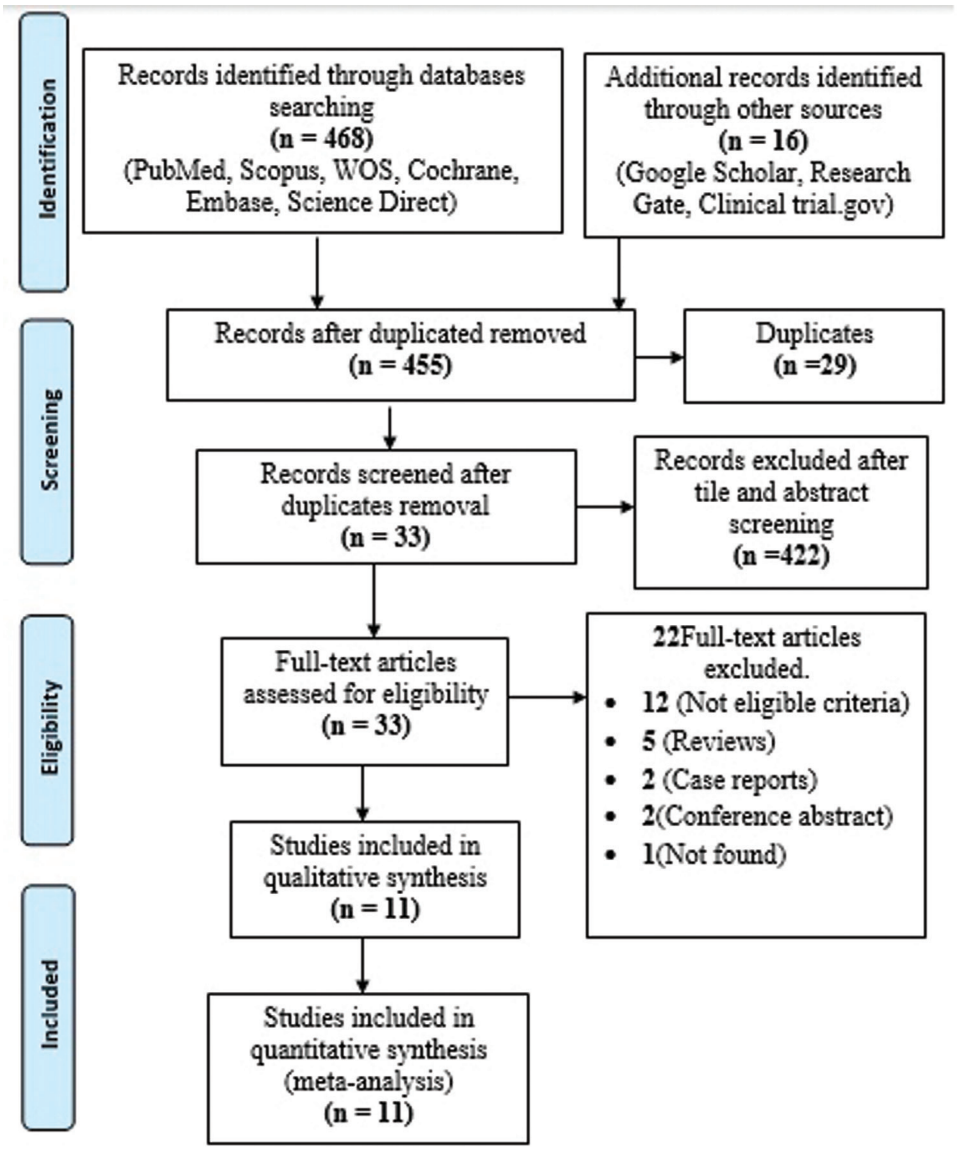
Risk of bias/quality assessment

Risk of bias was evaluated by the Cochrane handbook of systematic reviews of interventions 5.1.0, which included the following risks: selection bias 'through random sequence generation and allocation concealment', selective reporting, attrition bias, performance bias through blinding of participants, and personnel, detection bias through blinding of outcome assessment. Each bias domain is recorded as one of the following: low risk, high risk, or unclear risk. Prospective cohorts, retrospective cohorts, and case-controlled studies were evaluated using the National Institute of Health (NIH) tool for quality assessment. Visual demonstration of the risk of bias for the studies included was depicted using the ROBVIS (risk of bias visualization) tool (Fig. 2).

Statistical analysis

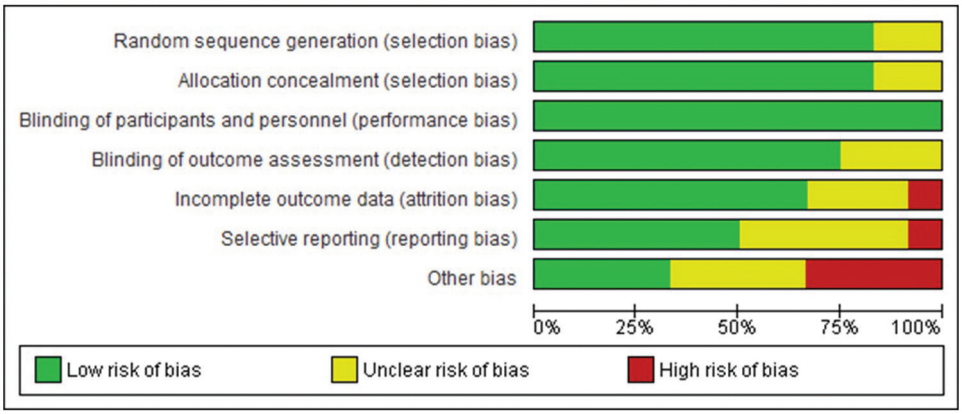
We conducted this meta-analysis using Open Meta Analyst (OMA) (Computer program) (Version 5.4. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Regarding the study

Figure 1



PRISMA Flowchart.

Figure 2



Visual demonstration of risk of bias assessment for the six randomized control trials included using the ROBVIS tool.

Table 1 Demographics of individual studies included with general information

1st Author	Year	Country	Study Design	Study Follow-up direction	Cohort Size	Mean Age (years)	PostOperative Infections	PostTraumatic Defect	Nonunion	Acute Bone Loss
Apard	2010	France	RC	Retrospective	12	40.67	7	12	1	12
Azi	2016	Brazil	RC	Retrospective	33	33	23	33	-	-
El-Alfy	2015	Egypt	PCS	Prospective	17	43.12	17	12	5	-
Gupta	2016	India	PCS	Prospective	9	35.44	8	9	-	-
Karger	2012	France	RC	Retrospective	84	32	41	84	14	84
Moghaddam	2015	Germany	PCS	Prospective	50	47.8	35	50	15	50
Obert	2016	France	PCS	Prospective	9	38.2	0	9	-	-
Olesen	2015	Denmark	RC	Retrospective	8	45.63	3	8	-	-
Scholz	2015	Germany	RCC	Retrospective	13	41.4	13	8	0	-
Taylor	2015	USA	RCS	Retrospective	69	42.3	7	69	-	69
Wang	2016	China	RC	Retrospective	32	40.03	32	32	2	-

PCS, Prospective Case Series; **RC**, Retrospective Cohort; **RCC**, Retrospective Case Control; **RCS**, Retrospective Case Series.

outcomes, risk ratio (RR) with 95% confidence interval (CI) was used for dichotomous variables, while the mean difference (MD) and 95% CI were used for continuous variable outcomes. Cochrane's *P* values and I2 were tested to examine heterogeneity among the studies. High heterogeneity most likely existed due to the clinical and methodological factors, so the random effect model was adopted in this meta-analysis even I2 was small.

Results

Study demographics and general information on the included studies are demonstrated in Table 1.

Literature search and type of study

We performed a thorough electronic search of literature that compared the use of a ring fixator or plating in tibial shaft fracture patients treated with the Masquelet technique. While searching the indicated keywords in the electronic databases (PubMed/MEDLINE, Cochrane, Scopus, Web of Science, EMBASE, Science Direct, Google Scholar, and Clinicaltrials.gov), a total of *n* = 484 articles were found, which underwent initial screening (abstract, titles, article type, and if it followed the inclusion/exclusion criteria of this study). After removal of duplicates (*n* = 29), screening the titles and abstracts (*n* = 422), and assessing article eligibility based on inclusion and exclusion criteria (*n* = 22), a total of 11 articles were included in the quantitative and qualitative analysis (Fig. 1). From the 11 studies analyzed, five were prospective/retrospective and six were randomized controlled trials.

Risk of bias assessment

All articles included in the quantitative and qualitative analysis were individually analyzed by two reviewers. The criteria tool assessed the following: study design, characteristics of patient population, patient assignment, method for data collection, inclusion/exclusion criteria, and method for quality assessment. Risk of Bias (ROB) in cohort studies was evaluated using the National Institute of Health (NIH) tool. (Table 2) All cohort studies demonstrated good or fair quality and non had a high ROB. (Fig. 2) For the cohort studies, Apard and colleagues demonstrated good quality overall using the NIH tool, while the other cohorts (Azi and colleagues, Karger and colleagues, Olesen and colleagues, and Wang and colleagues) demonstrated fair quality overall which was a result of unreported outcomes/measures that are mentioned in this tool. For the six randomized controlled trials, the risk of bias quality was good to moderate overall. Moderate quality was associated with reporting/attrition bias for the intervention. (Fig. 2).

Outcome results

Surgical site infection (SSI)

SSI was either reported as Superficial or Deep SSI in patients with tibial shaft fracture that had total bone loss of greater than or equal to 6 cm. SSI was determined using both clinical and laboratory analysis. Regarding superficial SSI, pooled analysis revealed a significant difference between the ring Fixation compression or plating fixation with Masquelet after a 12-month follow-up (RR = 0.034; 95% CI: [0.005, 0.064], 18/336 patients; *P* value < 0.001). Therefore, patients who underwent a plating fixation and Masquelet had a higher risk of developing superficial surgical site infections compared with those who underwent ring fixation compression and Masquelet. (Fig. 3).

Regarding Deep SSI (Fig. 3), pooled analysis demonstrated no significant difference between the risk of developing a Deep SSI in both techniques after a 12-month follow-up (RR = 0.039; 95% CI: [0.012, 0.067], *P* value = 0.088). Pooled studies for Deep SSI were homogenous (I2=39.08) and for the superficial SSI, the pooled studies demonstrated heterogenicity (I2 = 69.61), which was subsequently resolved via the exclusion of the study done by El-Alfy and Ali.

Table 2 Quality assessment of cohort studies using the National Institute of health (NIH) tool/ Questionnaire

Domains:	Authors:				
	Apard	Azi	Karger	Olesen	Wang
Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y
Was the study population clearly specified and defined?	Y	Y	Y	Y	Y
Was the participation rate of eligible persons at least 50%?	Y	Y	Y	Y	Y
Were all the subjects selected or recruited from the same or similar populations?	Y	Y	Y	Y	Y
Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	Y	Y	Y	Y	Y
Was a sample size justification, power description, or variance and effect estimates provided?	NR	NR	Y	NR	NR
For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	NA	NA	NA	NA	NA
Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	NR	Y	NR	NR	Y
For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as a continuous variable)?	NA	Y	NA	NA	Y
Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	NR	Y	NR	NR	Y
Was the exposure(s) assessed more than once over time?	NA	NA	NA	NA	NA
Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y
Were the outcome assessors blinded to the exposure status of participants?	Y	Y	Y	Y	Y
Was loss to follow-up after baseline 20% or less?	Y	Y	Y	Y	Y
Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	NA	NA	NA	NA	NA
Total scores (Yes = 1, No = 0.5, NR and NA and CD = 0)	13	9	10	9	11
Quality rating: good (14-13 points) or fair (9-12 points) or poor (8-0 points)	GOOD	FAIR	FAIR	FAIR	FAIR

CD, cannot determine; **N**, No; **NA**, not applicable; **NR**, not reported; **Y**, Yes.

There was no significant difference between superficial and deep SSI, but both had an incidence of 5% after a 12-month follow-up.

Post-operative failure

Post-operative failure was defined as graft resorption in absence of bone union or failure of graft maturation. Using pooled analysis, a significant difference was found between the occurrence of post-operative failure (12-month follow-up) in both techniques, with plating fixation and Masquelet having the higher risk of operative failure (RR = 0.191; 95% CI: [0.122, 0.260], 62/336 patients; *P* value = 0.003) compared with the ring fixation and Masquelet. (Fig. 4) The pooled studies were heterogeneous (I2 = 61.88%), which could not be resolved due to the high variation between the studies that reported postoperative failure as an outcome.

Risk of refracture

Potential predisposing factors that cause refracture are BMI, sex, underlying pathological bone diseases, immune mediated destruction, and improper placement/ alignment of bone during repair. Based on the pooled analysis, a significantly higher risk of refracture was demonstrated in the group of patients that underwent plating fixation and Masquelet (RR = 0.136; 95% CI: [0.068, 0.204], 53/336 patients; *P* value < 0.001) compared with those who underwent ring fixation compression following a 12-month follow-up. (Fig. 4) The pooled studies were heterogeneous (I2 = 90.6%) and the heterogeneity could not be resolved due to the high variation between the included studies regarding the outcome of refracture.

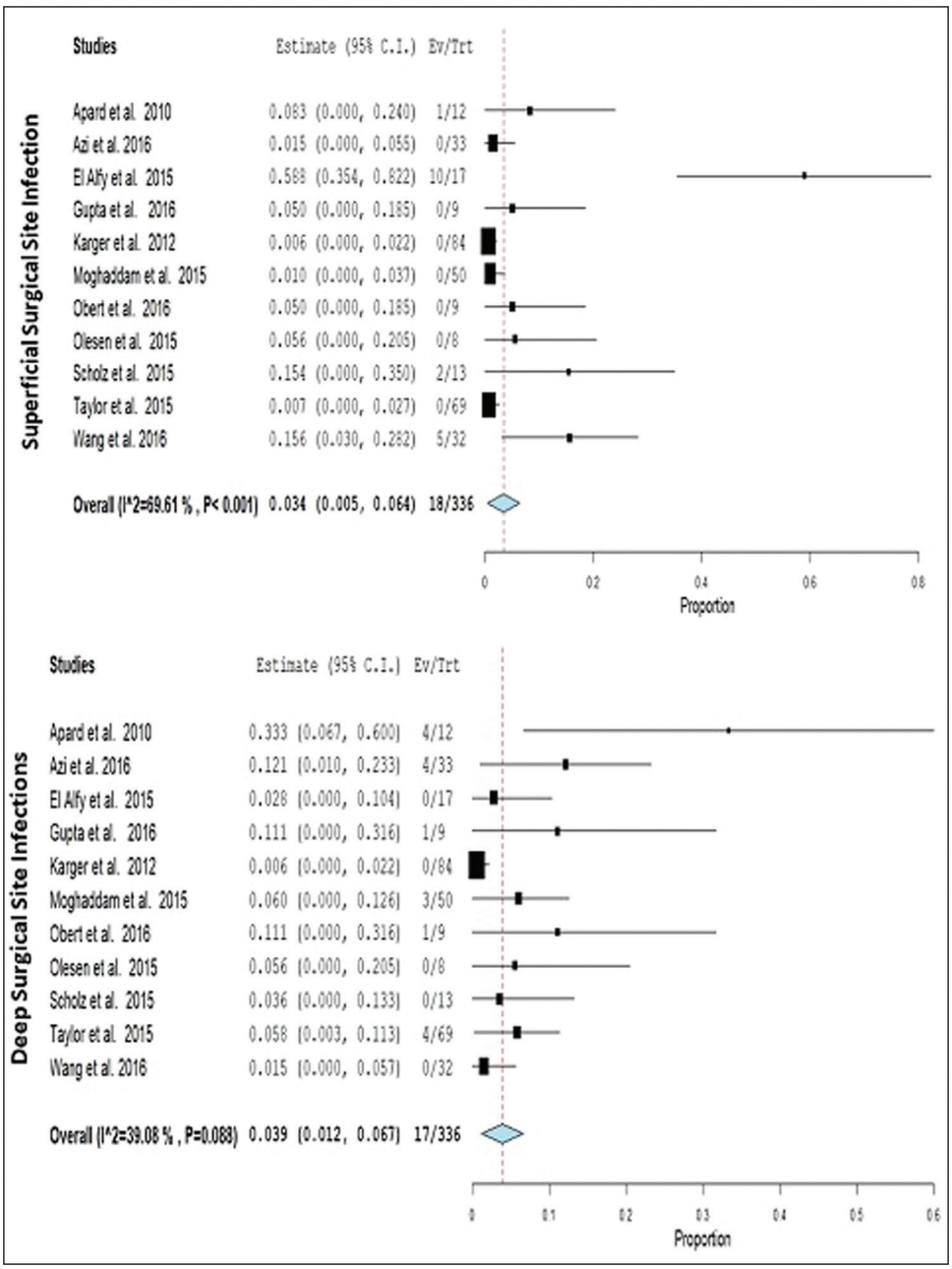
Risk of stiffness and decreased range of motion (ROM)

Analysis revealed significantly higher risk of developing stiffness and decreased range of motion in patients who underwent plating fixation and Masquelet (RR = 0.166; 95% CI: [0.92, 0.240], 59/336 patients; *P* value < 0.001) compared with ring fixation compression after a 12-month follow-up. (Fig. 5) The pooled studies were heterogeneous (I2 = 91.46%) and the heterogeneity could not be resolved due to the high variation between the included studies regarding the outcome of stiffness.

Wound and soft tissue disclosure

A significant positive result regarding the risk of occurrence of wound and soft tissue disclosure after a 12-month follow-up (RR = 0.045; 95% CI: [0.015, 0.076], 20/336 patients; *P* value = 0.026), which means that a higher risk of wound and soft tissue disclosure was demonstrated in patients undergoing plating fixation with Masquelet compared with the ring fixation compression. (Fig. 5) The heterogenicity of the studies (I2=50.81%) could not be resolved due to the

Figure 3



Forest plot diagram depicting outcome results of superficial and deep surgical site infections.

significant variation between the studies that included wound and soft tissue disclosure as an outcome.

* A significant increase in soft tissue disclosure and decreased ROM 12-months postoperatively was noted. The pooled estimate revealed that 18% of patients had decreased ROM and 6% of the patients demonstrated soft tissue disclosure.

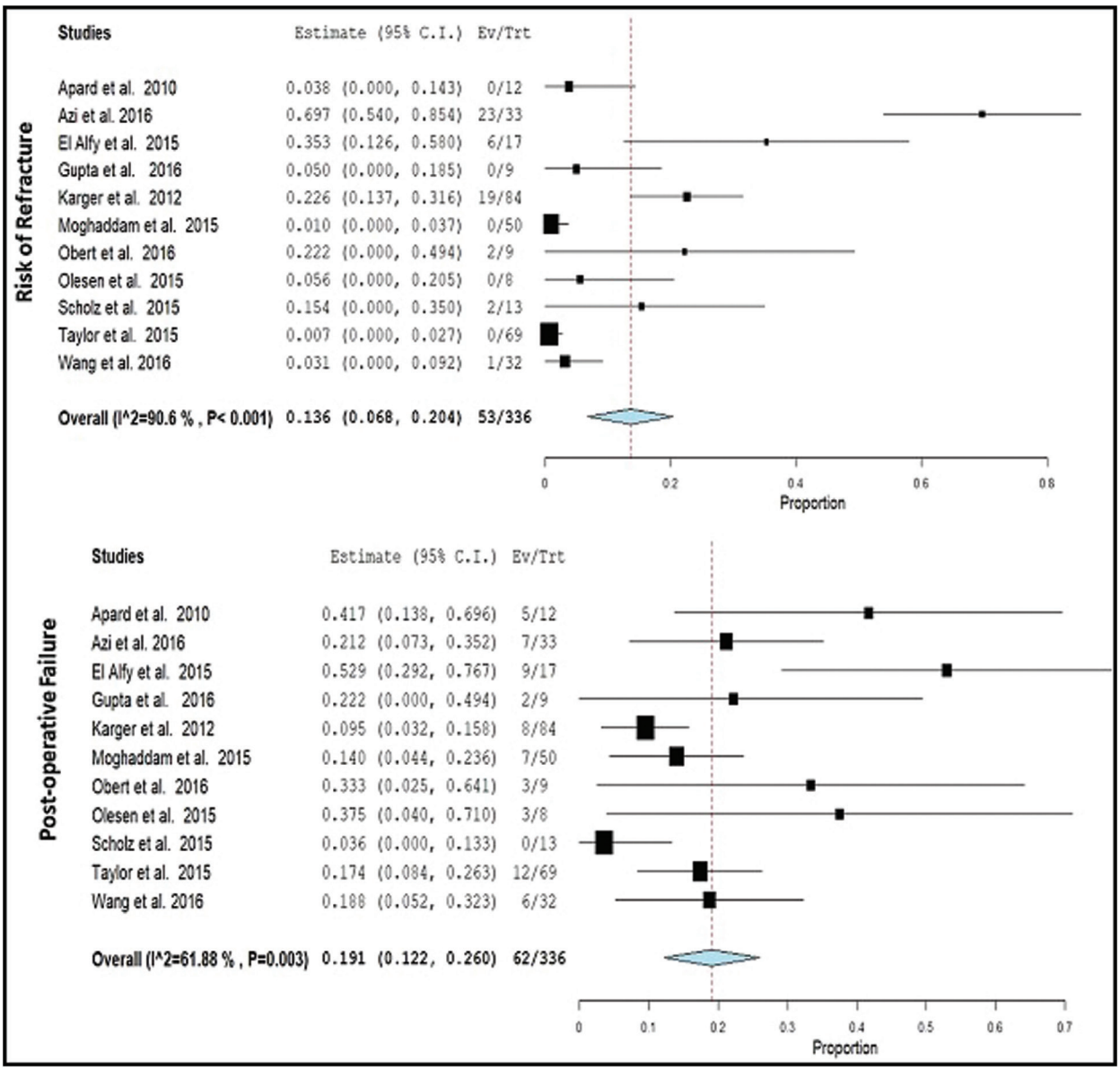
* A significant difference was seen between postoperative failure and the risk of refracture after a 12-month follow-up. Analysis showed an 18% risk of postoperative failure and a 16% risk of refracture postoperatively.

* Overall, the results of this systematic review and metanalysis demonstrate that patients who underwent the plating fixation + Masquelet technique had greater risks of developing superficial surgical site infections, stiffness, decreased range of motion, wound and soft tissue disclosure, refractures, and had greater risk for postoperative failure in comparison to the ring fixation compression + Masquelet technique. In terms of deep surgical site infections, there was no significant difference between the two techniques.

Discussion

Surgical repair of long bone fractures is a complex and tedious process Taylor and colleagues, Scholz and colleagues

Figure 4



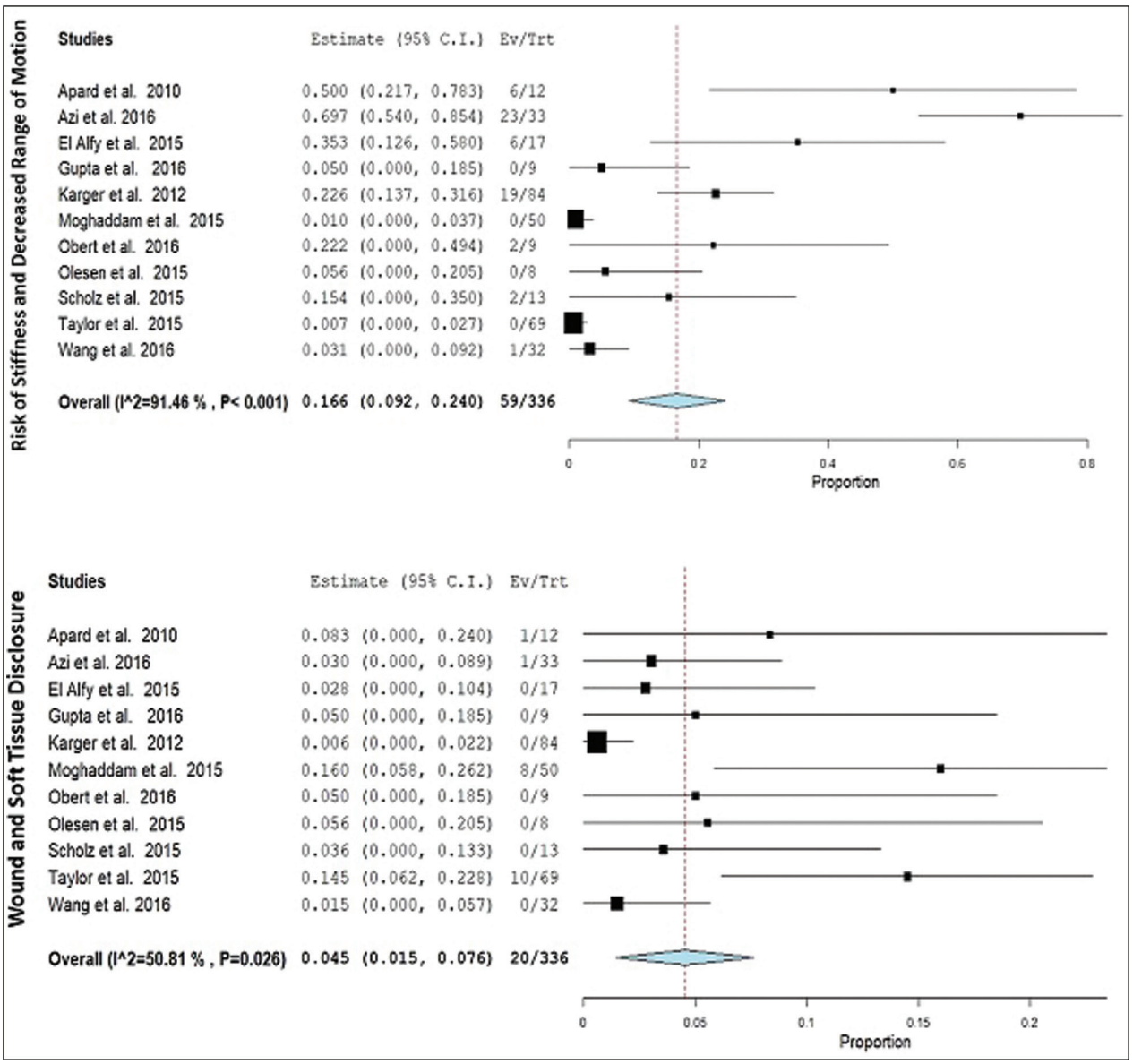
Forest plot diagram depicting outcome results of risk of refracture and postoperative failure.

[8–11]. Compared with most long bone fractures, tibial shaft fractures are predominately open fractures since the medial surface is adjacent to subcutaneous tissue. Treatment goals for long bone fractures include skeletal stabilization and preservation of optimum function. Methods of repair include intramedullary nailing, plating, external fixation, grafting, and amputation depending on the severity and extent of tissue damage. The Masquelet technique is indicated for the treatment of traumatic bone defects or surgical debridement Moghaddam and colleagues, Gupta and colleagues [12–14].

The purpose of this meta-analysis is to evaluate studies which compared the safety and efficacy of Ring Fixator and Plating during the Masquelet Technique for the treatment of tibial shaft fractures. A total of 11 studies were included with a total cohort of *n*=371 patients.

Postoperative failure was defined as graft resorption in absence of bone union or failure of graft maturation Taylor and colleagues, Obert and colleagues, Gupta and colleagues [8,10,14]. Compared with the ring fixation technique, Masquelet with plating patients demonstrated higher risks of postoperative failure throughout the 12 months follow-up [P = 0.003]. Postoperative failure may be potentiated by infection, extensive bone and soft tissue trauma, and mitigating medical conditions Azi and colleagues, El-Alfy and Ali.[15,16]. Karger and colleagues concluded that postoperative failure was associated with severe functional complications that resulted in permanent dysfunction or even amputation [13]. Interestingly, there is no significant correlation between the time of union and the extent of tissue defect Karger and colleagues, Apard and colleagues [13,17].

Figure 5



Forest plot diagram depicting outcome results of wound/soft tissue disclosure and decreased range of motion/stiffness.

Postoperative infections remain the primary complication. Surgical site infections were determined using the following markers: Pain, swelling, redness, pus, and sinus development [2]. Confirmatory labs included elevated erythrocyte sedimentation rate (ESR), C-reactive protein, and white blood cells. Our results demonstrated that patients undergoing plating fixation + Masquelet technique had higher risks [P < 0.001] of developing superficial surgical site infection (12 months follow-up), than those who underwent ring fixation + Masquelet. There was no significant difference between superficial and deep surgical site infection for both the plating and ring fixation technique. Bacterial cultures from surgical site infections demonstrated Staphylococcus Aureus (more common) and *Staphylococcus Epidermidis* Moghaddam and colleagues, El-Alfy and Ali, Apard and colleagues [12,16,17]. Infections were treated with empirical antibiotics for a minimum of one week. Few patients with postoperative failure (nonunion) developed septic complications that required successive operations Obert and colleagues, Karger and colleagues [10,13].

Risk of refracture, stiffness, and decreased range of motion was significantly [P < 0.001] greater in the plating verses the ring fixation technique. Patients who underwent the plating technique also had greater risk of developing wound and soft tissue disclosure [P = 0.026]. Olesen and colleagues noted that nailing seems to improve outcomes compared with the plating [9]. It shortens treatment time, reduces the amount of bone graft needed, aligns the bone, and should be considered when feasible. Higher risk of postoperative infection, nonunion, and postoperative failure may be considered potentiating factors for an increased risk of

stiffness and decreased range of motion demonstrated in this technique Scholz and colleagues, Moghaddam and colleagues [11,12]. Limited mobility and stiffness may be the result of a long-standing infection, excessive tissue removal (depending on severity of the trauma), and postoperative complications that occur at the time of operation or during follow-up.

Evidently, the results of this study suggest that overall, plating fixation with the Masquelet technique had higher risks for developing infection, postoperative failure, wound disclosure, and stiffness and decreased mobility. These outcomes were demonstrated within a 12-month follow-up. The conclusions of the individual studies suggest that induced membrane technique with cancellous autograft is a reliable but long technique, requiring 6 months without weight-bearing in its initial description Apard and colleagues [17]. This technique was effective for managing post-traumatic bone defects. External ring fixation with the Masquelet technique has proven to be a better alternative to plating and therefore should be implemented more often in the setting of tibial shaft fractures. Take note that, a full range of outcomes needs to be evaluated before making a definitive conclusion regarding the technique. These outcomes (which were not outcomes analyzed in this metanalysis) may include hospital stay, cost effectiveness, the need for follow-up surgeries/ interventions, etc.

Conclusion

Tibial fractures are one of the most common long bone fractures. There are numerous techniques that can be used to treat long bone fractures. In this systematic review and metanalysis, we thoroughly investigate all the literature that compared the use of plating fixation of ring fixation compression during the Masquelet technique. Plating fixation with Masquelet technique had significantly higher rates of superficial surgical site infection, operation failure, refracture, stiffness with decreased ROM, wound and soft tissue disclosure than ring fixation compression. Insignificance difference between them was detected regarding the occurrence of deep surgical site infection (SSI). Future studies with larger sized cohorts should be conducted. The results of this study could be used to update or develop guidelines and protocols.

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Author Contributions

None.

Ethical Approval

This study does not contain any studies involving human or animal participants performed by any of the authors.

Consent to Participate

This review did not involve any human/animal subjects and therefore did not require participation consent.

Consent to Publish

Not applicable.

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Conflicts of interest

Competing Interest – The authors have no relevant financial or non-financial interests to disclose.

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