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A Systematic Review of Operative Fixation of Patellar Fractures and Outcomes

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Abstract

Introduction: Patellar fractures are potentially debilitating injuries, and surgical intervention for these injuries aims to restore knee extensor function and congruency of the articular surface while maintaining comfort. High rates of dissatisfaction with patellar fixation have led to the development of novel fixation methods, but the relative efficacies of these fixation methods compared to previous methods remain unclear. An understanding of the outcomes of patellar fixation methods will enhance clinical decision-making for patellar fixation and provide a basis from which new methods can be developed.

Methods: A systematic review was conducted to identify all publications studying outcomes of different fixation methods from 1991-2021. Data from studies documenting rates of reoperation, nonunion, and complications including infection in adult patients with patellar fractures were recorded. Meta-analyses were performed on pooled proportions of union rate, complication rate, and hardware removal rate to compare the different patellar fixation methods.

Results: Initially 604 studies were identified; after screening, 20 studies were included in this review and meta-analysis. Using meta-analysis methods, the union rate was 99% [95% CI 0.97-0.99] for techniques using a tension band construct while it was 100% [95% CI 0-1.0] for all other techniques. However, there was substantial heterogeneity for other operative techniques compared to the tension band construct with respect to union rates. The corresponding complication rates were 12% [95% CI 0.04-0.30] and 7% [95% CI 0.03-0.14], respectively. Specifically, hardware removal rates were calculated at 27% [95% CI 0.06-0.66] and 10% [95% CI 0.01-0.54], for tension band constructs and all other techniques, respectively, although there was significant heterogeneity.

Conclusion: Tension band constructs and novel techniques for patellar fixation report similar rates of union, but novel techniques have lower complication and hardware removal rates.

Keywords: Patellar fractures; Fixation; Outcomes

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Introduction

Patellar fractures comprise approximately 1% of all fractures [1,2] and epidemiological data estimates that the prevalence of patellar fractures is 6.1 per 10,000 person-years [3]. The patella is a sesamoid bone that displaces the quadriceps tendon away from the knee joint's center of motion, facilitating angular motion of the joint and creating a mechanical advantage [4]. Displaced patellar fractures therefore compromise the knee's extensor mechanism and compromise the ability to ambulate [5,6]. Open Reduction and Internal Fixation (ORIF) is indicated for fractures with displacement of greater than 3 mm, articular incongruity of 2 mm or more, or a disrupted extensor mechanism [7]. The goals of surgery include restoring the knee extensor function and congruency of the articular surface.

Modified tension band is the most commonly reported method for patellar fixation [8,9]. The tension band principle converts anterior tension forces to compressive forces at the articular surface [10,11]. While rates of nonunion have been reported to be around 1.3% [12], complication rates, primarily painful or prominent hardware, have been as high as 54% [13], and warrant frequent hardware removal and reoperation [5,11,12]. Additionally, Patient-Reported Outcomes (PROs) remain poor after ORIF [14]. Poor outcomes of patellar fixation have led to the introduction of many novel fixation methods, but the relative efficacies of these new methods remain unclear. An understanding of the outcomes of newer patellar fixation compared to classic methods of fixation will enhance clinical decision-making for patellar fixation and provide a basis from which new methods and improvements may be developed. The purpose of this study is to determine the rates of union, hardware removal, and complications among various newer and classic methods of patellar fixation through a systematic review and meta-analysis of the patellar fracture literature.

Materials and Methods

Study selection and eligibility

We conducted a systematic review of patellar fracture publications between the years of 1991 and 2021 using the PubMed database on June 7th, 2021. All studies were identified using the following advanced query search terms, adapted from Dy et al. [11]: (("1991"[Date-Entry]: "2021"[Date-Entry])) AND ((ORIF OR "Open Reduction Internal Fixation" OR "Open Reduction" OR "Internal Fixation" OR "fracture fixation, internal" [MeSH Terms] OR Orthopedic Fixation Devices [MeSH Terms] OR Fractures, Bone/surgery [MeSH Terms]) AND (patella/injuries OR ["fracture" OR "fractures"] AND Patella) AND (Postoperative Complications OR Treatment Outcome OR Adverse Effects OR reoperation OR second-look surgery OR Equipment Failure OR "Hardware Failure" OR posttraumatic arthritis OR Device Removal OR Follow-Up Studies OR Retrospective Studies OR retrospective* OR Complications*)) [15-20]. Filters were used to include only studies in English, clinical studies, clinical trials, comparative studies, controlled clinical trials, observational studies, Randomized-Controlled Trials (RCTs), and technical reports. This systematic review protocol was not prospectively registered.

After the initial search, the titles and abstracts of each study were reviewed by one reviewer to exclude studies that were 1) cadaveric or biomechanical studies only, 2) case reports, technique descriptions, systematic reviews, or other review articles without an associated case series, and 3) studies involving the patella but not pertinent to patellar fractures. A review of full texts was performed, and studies were excluded if there were no reports of reoperation, nonunion, infection, or other complication rates.

Data extraction

Data points extracted by two reviewers from each article were the year of publication, number of patients, number of fractures, union rate, infection rate, reoperation rate, rates of reported postoperative pain, complication rate, and rates of implant removal, if provided. Functional scores including range of motion, thigh circumference difference, Visual Analogue Scale (VAS) for pain, Lysholm score, Tegner score, Hospital for Special Surgery (HSS) knee score, Turba score, Bostman score, and Iowa knee score were recorded, if provided. SF-39, Oxford knee, and KOOS scores for PROs were recorded [21-25]. Missing data were noted; however, studies were retained only if they had complete data on rates of union or nonunion, complications, and hardware removal.

Data analysis

Meta-analyses were separately performed for pooled proportions of union rate, complication rate, and hardware removal rate. In each case, to determine the pooled proportion, the variances of the raw proportions were stabilized by using a Freeman-Tukey-type arcsine square root transformation and the pooled proportions were calculated as the back-transform of the weighted mean of the transformed proportions, using fixed or random effects models. We tested the significance of heterogeneity between studies using the Q test and random effects models were chosen if the Q test was significant. Otherwise, fixed effects models were applied. Forest plots were used for the presentation of the outcome proportions with confidence intervals from individual studies, pooled proportions, and test for homogeneity.

Risk of bias assessment

The National Heart, Lung, and Blood Institute (NHLBI) quality assessment tools [14] for case series, observational studies, case control studies, and randomized-controlled trials were used to assess risk of bias and quality of each study included. All studies were reviewed by one reviewer. Reporting bias was measured qualitatively using the same NHLBI tool.

Results

The initial search yielded 604 results for screening, and after applying the filters, 519 results were excluded (Figure 1). Title and abstract review excluded 48 studies. Review of the full text of the remaining 37 articles was performed, and an additional 17 studies were excluded because they lacked reports of reoperation, nonunion, infection, or other complications. The remaining 20 articles were reviewed in detail and the relevant data were extracted for review. Of the studies included, one was a case-control study, three were case series, three were RCTs, and 13 were observational cohort studies (Table 1). Fracture severity could not be compared due to the multiple classification systems used in the articles. Similarly, PROs could not be evaluated because 17 of the included studies did not list them (Table 1). The full review protocol can be found in the supplemental materials.

The risk of bias assessment for the included observational cohort studies resulted in 11 being rated as “good” and 2 being rated as “fair” (Table 2). All included RCTs (Table 3), case-control (Table 4), and case series (Table 5) studies were rated as “good”. Reporting bias arose from the inclusion criteria, as this study only includes studies that reported each outcome variable [26].

Tension band constructs were the most reported while compressive external fixation was a far second. Of the included studies, 12 studied tension band constructs, two studied fixed-angle plate, two studied cerclage wiring constructs, two studied cable-pin systems, and there was one study each of partial patellectomy, novel

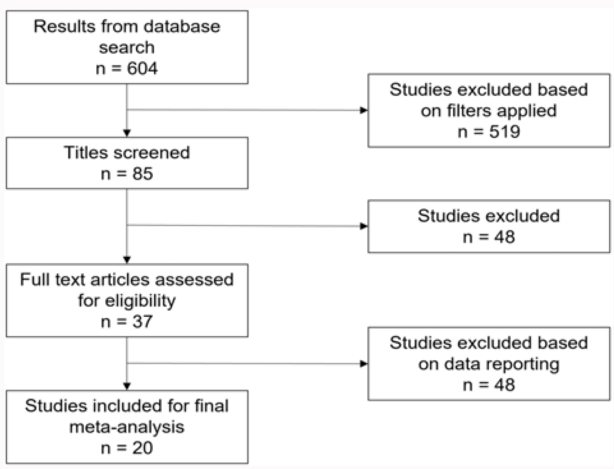

Figure 1: Flow diagram illustrating study selection process.

Table 1: Characteristics of studies included in meta-analysis.

Reference	Fixation Method	No. Fractures	No. hardware Removal	No. union	No. complications	Hardware Removal rate	Union rate	Complication rate	PRO Measure used
Wild et al. [15]	Fixed angle plate	20	4	20	2	20%	100%	10%	KOOS, Oxford
Lebrun et al. [13]	Tension band construct	27	14	27	3	51.90%	100%	11.10%	SF-39, KOOS
Lorich et al. [16]	Novel patella fracture fixation construct	33	0	33	0	0%	100%	0%	None
	Tension band construct	25	0	25	1	0%	100%	4%	
Cho et al. [17]	Tension band construct	30	4	29	1	13.30%	96.70%	3.30%	None
Lazaro et al. [4]	Figure-of-eight wiring and/or sutures	30	11	30	2	36.70%	100%	6.70%	None
Moore et al. [18]	Fixed angle plate	36	2	36	1	5.60%	100%	2.80%	None
Yan et al. [19]	Adjustable patella grapple	45	45	45	11	100%	100%	24.40%	None
	Tension band construct	33	33	33	0	100%	100%	0%	
Tian et al. [20]	Tension band construct	101	5	98	11	5%	97%	10.90%	None
Gosal et al. [21]	Stainless steel wire	21	8	21	5	38.10%	100%	23.80%	None
	5 Ethibond	16	0	16	1	0%	100%	6.25%	
Tan et al. [22]	Tension band construct	55	12	55	4	21.80%	100%	7.30%	None
Sun et al. [23]	Modified cerclage wiring	38	0	38	0	0%	100%	0%	None
Wardak et al. [24]	Compressive external fixation	84	84	84	12	100%	100%	14.30%	None
Mao et al. [25]	Cable pin system (minimally invasive)	20	4	20	2	20%	100%	10%	None
	Tension band construct	20	15	20	13	75%	100%	65%	
Lin et al. [12]	Closed reduction and percutaneous cannulated screw fixation	26	2	26	3	7.70%	100%	11.50%	None
	Tension band construct	26	11	26	14	42.30%	100%	53.80%	
Kyung et al. [7]	Tension band construct	23	12	21	9	52.20%	91.30%	39.10%	None
	Novel ring pin	25	2	25	1	8%	100%	4%	
Tian et al. [20]	Cable pin system	34	0	34	1	0%	100%	2.90%	None
	Tension band construct	39	5	39	9	12.80%	100%	23.10%	
Tang et al. [26]	Five-pointed star lattice sutures	25	0	25	0	0%	100%	0%	None
Lorich et al. [27]	Novel cage plate construct	9	1	9	0	11.10%	100%	0%	None
Chang et al. [28]	Tension band construct	10	6	10	3	60%	100%	30%	None
Zhang et al. [29]	Tension band construct	41	0	41	0	0%	100%	0%	None
	Patellotibial cerclage	22	10	22	10	45.50%	100%	45.50%	

Table 2: Results of risk of bias assessment for observational studies.

Question	Kyung et al. [7]	Lebrun et al. [13]	Lorich et al. [16]	Tian et al. [20]	Yan et al. [19]	Zhang et al. [29]	Gosal et al. [21]	Sun et al. [23]	Wardak et al. [24]	Lazaro et al. [4]	Tang et al. [26]	Moore et al. [18]	Wild et al. [15]
1. Was the research question of objective in this paper clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the study population clearly specified and defined?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Was the participation rate of eligible persons at least 50%?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. Was a sample size justification, power description, or variance and effect estimates provided?	No	No	No	No	No	No	No	No	No	No	No	No	No
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
7. Was the timeframe sufficient so that one could reasonable expect to see an association between exposure and outcome if it existed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. 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 continuous variable)?	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes

9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
10. Was the exposure(s) assessed more than once over time?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12. Were the outcome assessors blinded to the exposure status of the participants?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
13. Was loss to follow-up after baseline 20% or less?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
15. Final rating	Good	Good	Good	Good	Fair	Good	Good	Good	Good	Good	Fair	Good	Good

Table 3: Results of risk of bias assessment for randomized-controlled trials.

Question	Lin et al. [12]	Tian et al. [30]	Mao et al. [25]
1. Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?	Yes	Yes	Yes
2. Was the method of randomization adequate (i.e., use of randomly generated assignment)?	Yes	Yes	Yes
3. Was the treatment allocation concealed (so that assignments could not be predicted)?	Yes	Yes	Yes
4. Were study participants and providers blinded to treatment group assignment?	No	No	No
5. Were the people assessing the outcomes blinded to the participants' group assignments?	No	No	No
6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?	Yes	Yes	Yes
7. Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?	Yes	Yes	Yes
8. Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?	Yes	Yes	Yes
9. Was there high adherence to the intervention protocols for each treatment group?	Yes	Yes	Yes
10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)?	Yes	Yes	Yes
11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?	Yes	Yes	Yes
12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?	No	No	No
13. Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?	Yes	Yes	Yes
14. Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?	Yes	Yes	Yes
15. Final rating	Good	Good	Good

Table 4: Results of risk of bias assessment for case control studies.

Question	Tan et al. [22]
1. Was the research question or objective in this paper clearly stated and appropriate?	Yes
2. Was the study population clearly specified and defined?	Yes
3. Did the authors include a sample size justification?	No
4. Were controls selected or recruited from the same or similar population that gave rise to the cases (including the same timeframe)?	Yes
5. Were the definitions, inclusion and exclusion criteria, algorithms or processes used to identify or select cases and controls valid, reliable, and implemented consistently across all study participants?	Yes
6. Were the cases clearly defined and differentiated from controls?	Yes
7. If less than 100 percent of eligible cases and/or controls were selected for the study, were the cases and/or controls randomly selected from those eligible?	NA
8. Was there use of concurrent controls?	No
9. Were the investigators able to confirm that the exposure/risk occurred prior to the development of the condition or event that defined a participant as a case?	Yes
10. Were the measures of exposure/risk clearly defined, valid, reliable, and implemented consistently (including the same time period) across all study participants?	Yes
11. Were the assessors of exposure/risk blinded to the case or control status of the participants?	NA
12. Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?	Yes
13. Final rating	Good

patella fracture fixation construct, figure-of-eight wiring, adjustable patella grapple, stainless steel wire, suture fixation, compressive external fixation, closed reduction and percutaneous cannulated screw fixation, novel ring pin, five-pointed star lattice sutures, and the novel cage plate construct. Eight studies evaluated more than one fixation method [27-30].

Table 5: Results of risk of bias assessment for case series studies.

Question	Chang et al. [28]	Cho et al. [17]	Lorich et al. [27]
1. Was the study question or objective clearly stated?	Yes	Yes	Yes
2. Was the study population clearly and fully described, including a case definition?	Yes	Yes	Yes
3. Were the cases consecutive?	Yes	Yes	Yes
4. Were the subjects comparable?	Yes	Yes	Yes
5. Was the intervention clearly described?	Yes	Yes	Yes
6. Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes
7. Was the length of follow-up adequate?	Yes	Yes	Yes
8. Were the statistical methods used well-described?	Yes	Yes	Yes
9. Were the results well-described?	Yes	Yes	Yes
10. Final rating	Good	Good	Good

To compare fixation methods, data for each were pooled for meta-analysis. The data spread reveals very little variation (τ^2=0.7675 for the tension band group and τ^2=0 for other operative techniques) for union rates (Figure 2) but high variation for complication and hardware removal rates (Figure 3, 4).

Union rate

The pooled union rate among all patellar fixation methods was 99%. The tension band constructs pooled rate of union was 99% [95% CI 0.97-0.99], while all other methods had a 100% [95% CI 0-1.0] union rate (Figure 2). Raw, un-pooled union rates had little range, from 97% to 100%, indicating the ubiquity of union for patellar fractures, regardless of operative technique. Therefore, nonunion rates are very low for all reported constructs. Heterogeneity among the samples for union rate was low, as I^2=0 for both tension band constructs and other operative methods.

Complications and hardware removal

The overall rates of complications (Figure 3) and hardware removal (Figure 4) were 8% and 17%, respectively. Reported complications included but were not limited to infection, hardware and fixative failure, hardware migration, refracture, and painful hardware. Complications and hardware removal rates were highest in fractures treated with a tension band construct compared with all other groups, as the tension band group had a pooled complication rate of 12% [95% CI 0.04-0.30] compared to 7% [95% CI 0.03-0.14] in the all-other methods group, and a pooled hardware removal rate 27% [95% CI 0.06-0.66] compared to 10% [95% CI 0.01-0.54]. Heterogeneity was high for complication and hardware removal rate for tension band constructs, as I^2=80% for complication rate

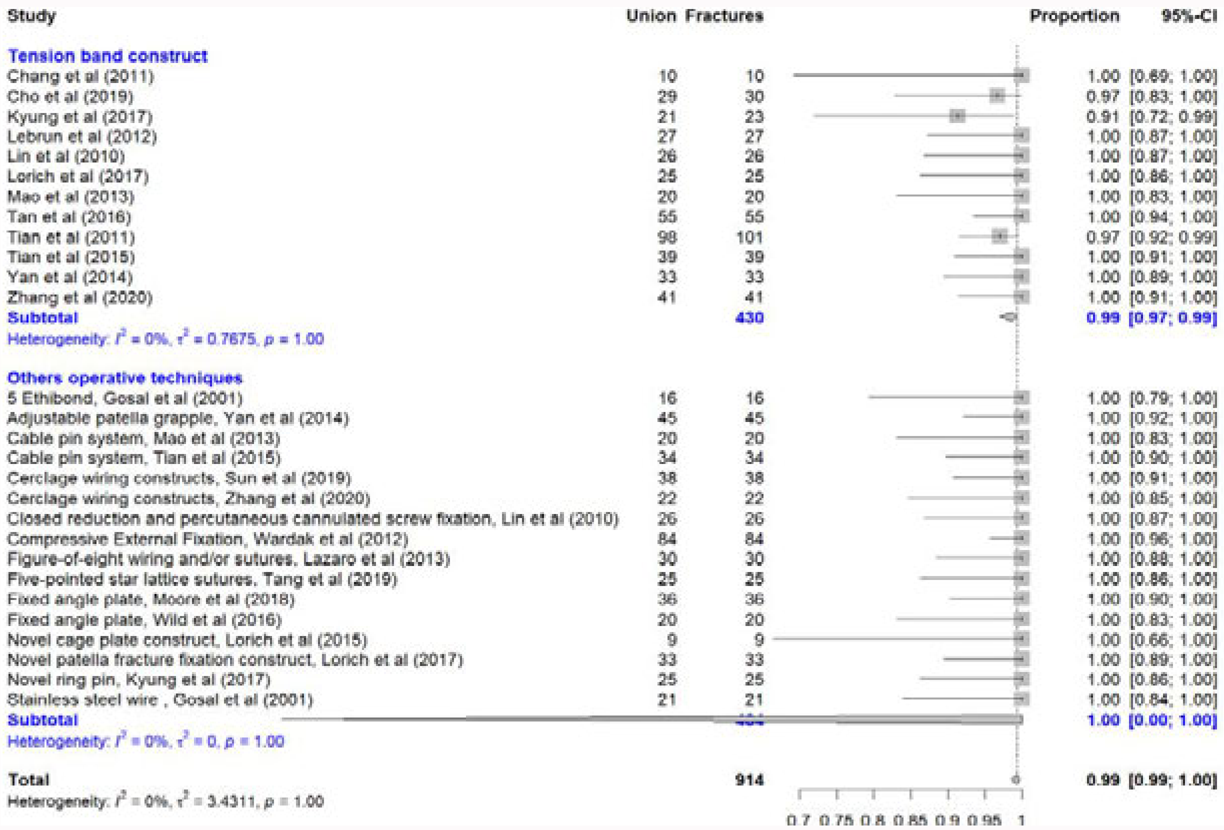

Figure 2: Forest plot showing fracture union rates between the tension band and other fixation groups. CI: Confidence Interval.

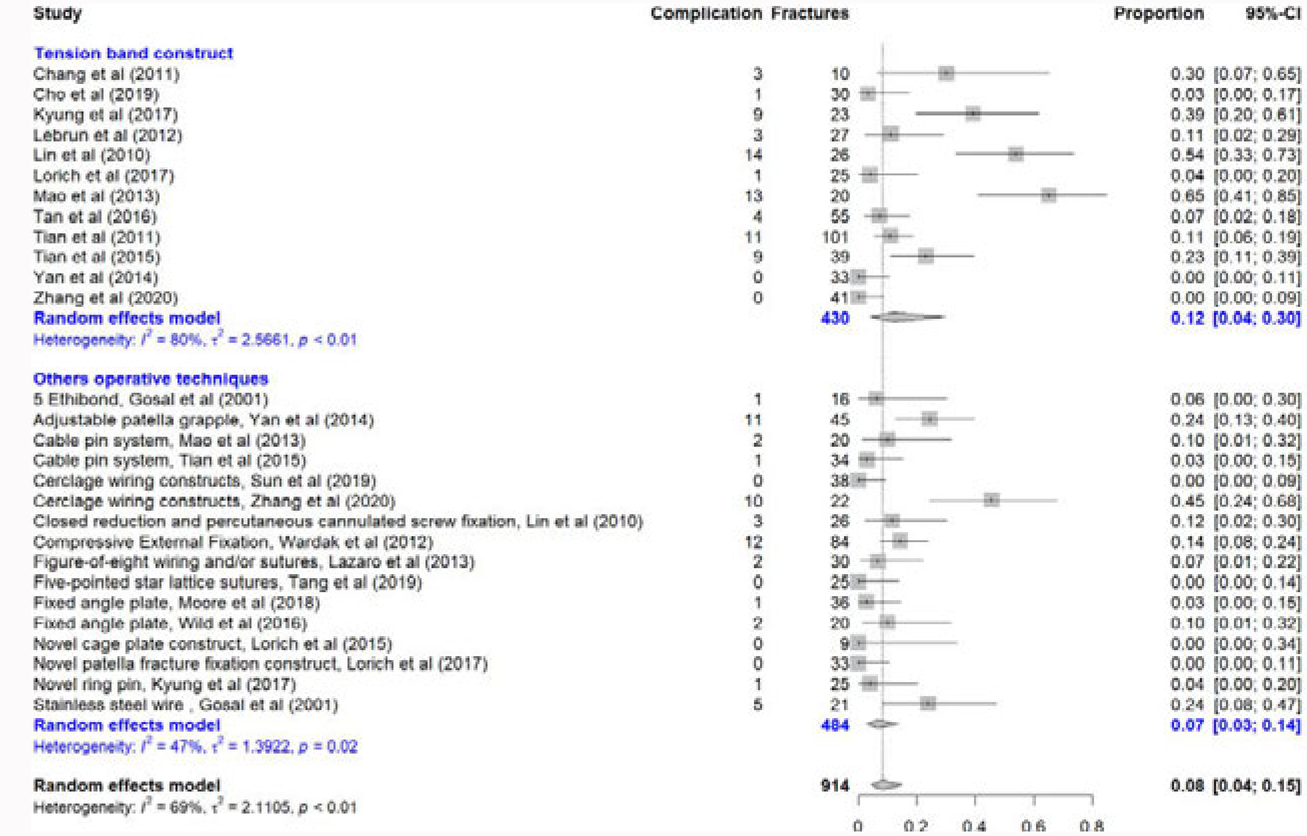

Figure 3: Forest plot showing complication rates between the tension band and other fixation groups. CI: Confidence Interval.

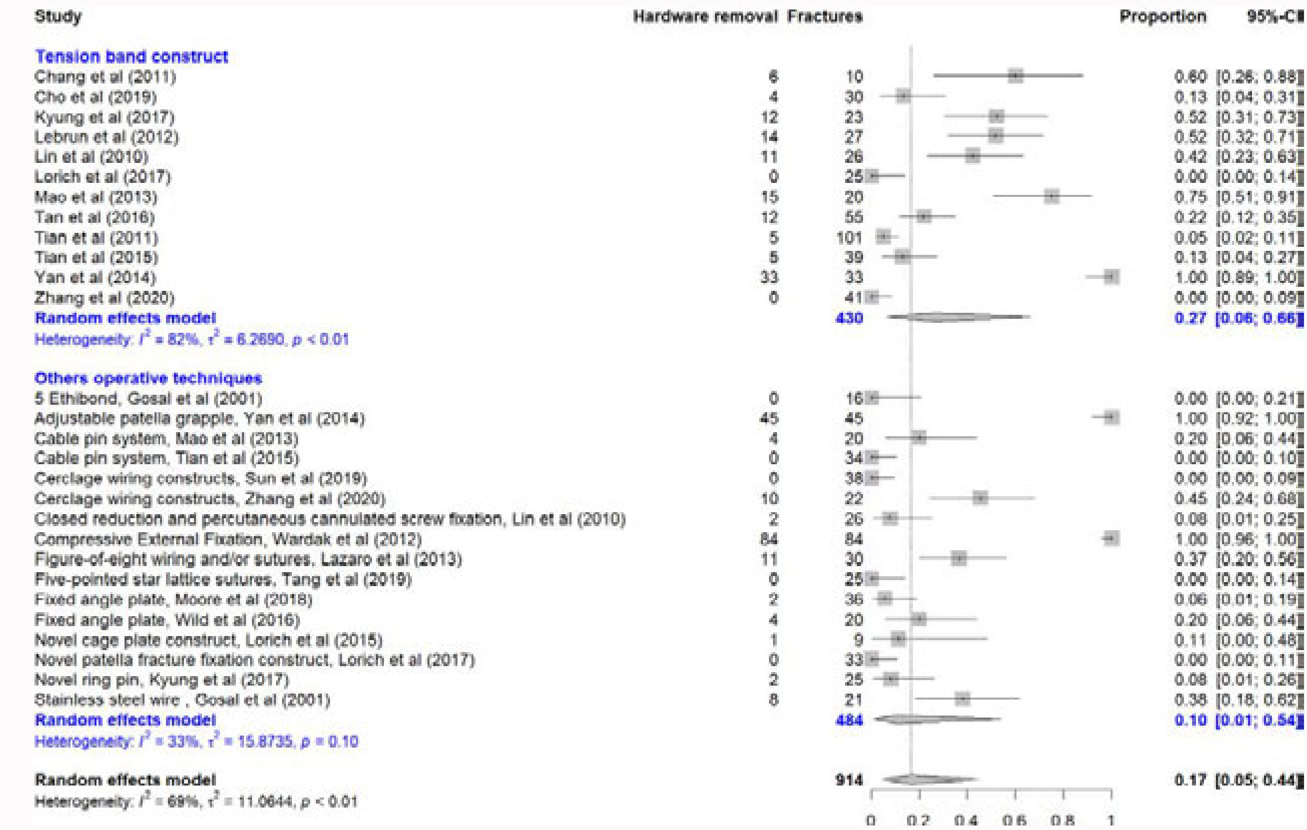

Figure 4: Forest plot showing rates of hardware removal between the tension band and other fixation groups. CI: Confidence Interval.

and I^2=82% for hardware removal rate. Heterogeneity for all other operative techniques was lower, as I^2=47% for complication rate and I^2=33% for hardware removal rate. Sources of bias in these results include fracture type and severity, differences in postoperative management, and incomplete control of confounding variables among the studies included.

Discussion

This study was conducted to identify rates of complication, hardware removal, and union among patients treated with traditional tension band constructs versus newer fixation methods to identify differences in outcomes of fixation between the two methods. To our knowledge, no other study has identified these pooled rates for methods of fixation other than tension band constructs. The union rate among all patellar fixation methods was 99%, which corroborates a previous meta-analysis that found a 98.7% union rate [12]. In our study, the only reports of nonunion occurred with tension band constructs, as 1.4% (6/430) of fractures had nonunion with tension band while none of the other operative methods had nonunion. Additionally, rates of complication and hardware removal were greater in tension band constructs (12% and 27%, respectively) than other pooled operative methods (7% and 10%, respectively). These lower rates of complication and hardware removal could lead to greater patient satisfaction with fixation methods other than tension band constructs.

Furthermore, while some studies reported PROs, different scoring systems were used which made direct comparison of PROs not possible. The studies that reported PROs used the KOOS, Oxford knee score, and/or SF-39 methods, though the vast majority [17] of included studies did not have PROs (Table 1). Since multiple scoring systems were used, it was not possible to pool the data and compare PROs. Patient satisfaction with patellar fixation is partially dependent on subjective measures, so more PRO reporting is necessary to better compare operative modalities for patellar fractures.

For complication and hardware removal rates, the tension band construct group demonstrated significant heterogeneity, most likely due to variations in clinical sampling. Fracture type, pattern, and severity included in the studies varied considerably. Postoperative management may also contribute to heterogeneity, as, in some studies, tension band constructs were removed as part of protocol rather than as a result of a complication. This was also seen in two other operative techniques: Closed external fixation and the adjustable patella grapple, though heterogeneity was lower overall in that sample. Lastly, sample sizes of the studies varied substantially across both groups, increasing heterogeneity.

The limitations of this study are those inherent to meta-analysis. Included studies did not report the same outcomes or use a uniform definition, so outcomes such as thigh circumference, range of motion, and functional scores could not be pooled and compared. Additionally, we did not stratify the study based on fracture type, so fracture severity could affect the primary outcomes. This was done primarily because fracture classification systems used among the studies were not uniform. PubMed was the only database used for this study and only studies that reported each of the three outcome variables were included, increasing reporting bias of the study. This systematic review protocol was not prospectively registered, though the protocol is available in supplemental information. Lastly, no sensitivity analyses were conducted.

Conclusion

Despite the study's limitations, our meta-analysis and literature review reveal that nonunion rates are extremely low for operative fixation of patellar fractures. And, although tension band techniques were much more commonly reported, this technique appeared to have higher complication and hardware removal rates when compared to other newer fixation methods. Future studies could also benefit from a standardized method of reporting fracture type and PROs, so that fracture and patient outcomes can be identified and compared.

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