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Original Research

Comparing the Efficacy and Safety of Metacarpal Neck Fracture Treatments: A Systematic Review and Network Meta-Analysis

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Purpose: Metacarpal neck fractures may perform well without operative intervention, but the current literature on this topic is fragmented and guidance on managing these injuries needs further refinement. We conducted a systematic review and network meta-analysis to provide a comprehensive evaluation of the various treatments available for these injuries.

Methods: We searched 3 electronic databases and included any study comparing interventions for metacarpal neck fractures. We conducted a Bayesian network meta-analysis for each outcome.

Results: We identified a total of 14 studies comparing: antegrade (AIMP) or retrograde (RIMP) intramedullary pinning, buddy strapping, transverse pinning (TP), functional bracing, plating, retrograde cross-pinning, a combination of retrograde cross-pinning and plating, and placement of an orthosis or casting. Although the results were not statistically significant, the effect estimates suggested more favorable pain reduction and functional improvement with AIMP compared with nonsurgical therapies and RIMP in the short term (3 months or less). However, differences between interventions at later follow-up were less extreme; data on short-term pain and function with surgical options outside AIMP and RIMP were unavailable. In addition, compared with both plating and TP, AIMP was associated with significantly higher risks for implant migration and neurological events. There were contrasting findings in union-related outcomes. Plating showed the earliest time to union (not statistically significant) but TP demonstrated the lowest risk for a delayed union.

Conclusions: This review demonstrated that although AIMP may be a viable surgical option for early symptomatic relief after a metacarpal neck fracture, it may also be associated with a greater likelihood of certain postoperative complications. Clinicians should consider patient preferences for the time frame of symptomatic relief when selecting the optimal treatment, and patients should weigh the advantages and disadvantages of each available option, especially when considering invasive surgery. Considering the lack of high-quality primary research investigating these interventions, future studies are needed to make more definitive conclusions.

Type of study/level of evidence: Therapeutic II.

Metacarpal fractures comprise approximately 42% of all hand fractures, estimating to cost over $2,000/hand fracture in Canada.[1,2] Most metacarpal fractures are isolated injuries and patients may perform well without operative intervention, but the current literature on this topic is underwhelming and guidance on managing these injuries needs further refinement.

Metacarpal fractures can be categorized according to where they occur along the bone; those classified as neck fractures are the

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most common.[3] Numerous treatment options available for metacarpal neck fractures have been investigated in comparative studies: antegrade (AIMP) or retrograde (RIMP) intramedullary pinning, buddy strapping (BS), transverse pinning (TP), functional bracing (FB), plating, retrograde cross-pinning (RCP), a combination of RCP and plating (RCP-P), and placement of an orthosis or casting (SC).[4–18] There is conflicting evidence concerning the efficacy of these treatments across a variety of both clinical and patient-reported outcomes. For example, one study demonstrated that intramedullary pinning was superior to transverse pinning, whereas another study comparing the same treatment options yielded no significant differences between the 2 techniques in outcomes such as, but not limited to, pain, grip strength, movement, and complication rates.[15,16] In addition, there is inconsistency across studies in terms of the outcomes used to assess the performance of these treatments.[5–18] Finally, with the limited literature comparing multiple different treatment options for metacarpal neck fractures, as well as the lack of definitive conclusions, physicians may currently find it difficult to make informed, evidence-based decisions for the management of these injuries.

Systematic reviews have been published on this topic in recent years. Corkum et al[19] published one in 2013 but did not perform a meta-analysis. Zong et al[20] released a network meta-analysis in 2015 analyzing the risk for any complication but did not include RIMP or RCP in the analysis and considered all conservative options to be one single treatment node. A number of additional studies on this topic have since been published. Furthermore, various conservative therapies exist (ie, BS, FB, and SC) that merit further analysis; a more detailed analysis of complications and patient-important outcomes (eg, pain and function) would be beneficial. Therefore, to obtain a clearer and more timely understanding of the differences in clinical and patient-relevant outcomes among the myriad metacarpal neck fracture interventions, a thorough assessment of the evidence on this topic was required. As such, we conducted this systematic review and meta-analysis to provide a current and comprehensive evaluation of the various treatment options for metacarpal neck fractures.

Materials and Methods

We conducted this systematic review and meta-analysis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[21] We did not previously register a protocol for this review. The study was funded by a research grant from Acumed (Hillsboro, OR). The funder had no role in the design, data collection, analysis, interpretation, or writing of this study, or the decision to submit the manuscript.

Search strategy

We performed a systematic search of 3 electronic databases (EMBASE, Cochrane, and MEDLINE) using the search terms listed in Appendix A (available on the Journal's Web site at www.jhandsurg.org) from database inception to April 30, 2019. We limited the search to articles published in English. Two reviewers assessed articles for eligibility in 3 stages: title, abstract, and full-text screening. If we were unable to retrieve an article, we excluded it from the review. We resolved any discrepancies through consensus, with input from a third party when required.

Eligibility criteria

We included randomized controlled trials (RCTs) and observational comparative studies (prospective or retrospective) that compared at least 2 different interventions for metacarpal neck fractures. We excluded studies that did not recruit skeletally mature patients (ie, studies that focused on pediatric or adolescent populations). Appendix B (available on the Journal's Web site at www.jhandsurg.org) details the comprehensive inclusion and exclusion criteria.

Data extraction and synthesis

We employed a standardized data collection form, using Microsoft Excel 2016 (Redmond, WA) for data extraction. We collected data from all included studies and resolved any discrepancies by consensus, with input from a third reviewer when required. For each study, we identified the study characteristics (ie, specific metacarpal and fracture type, number of participants, length of follow-up) as well as characteristics regarding patient populations and interventions that were examined in the studies (ie, patients' age, gender distribution, type of intervention).

We analyzed continuous variables ([1] pain [measured on a 100-point scale], [2] function [on a 100-point scale], [3] time to return to work or regular activities [measured in weeks], and [4] time to radiographic union or clinical union [in weeks] as well as dichotomous variables ([1] delayed union, [2] implant migration, and [3] neurologic event.

Descriptive data are reported as mean or median, along with the appropriate measure of dispersion. When possible, we conducted a Bayesian network meta-analysis (NMA) with the 95% credible interval (CrI) for a given outcome. We conducted all analyses using a random-effects model. Results of a meta-analysis are reported as risk ratios for dichotomous variables and mean differences (MD) for continuous data. We represented heterogeneity as I^2 values. All statistical analyses were performed using R software (version 3.5.0, *gemtc* package, R Core Team, 2018, Vienna, Austria). For any Bayesian NMA, we also calculated the surface under the cumulative ranking curve values to rank treatments.[22] We used the tool developed by Kennedy et al[23] to assess the quality of both randomized and nonrandomized studies.

Results

Search results

The electronic search retrieved 2,637 citations from the MEDLINE and EMBASE databases; 2,318 remained after deduplicating within OVID. The search from the Cochrane Library yielded 203 citations, which eventually resulted in a total of 2,481 citations to screen after further deduplication. We screened those titles and abstracts based on inclusion and exclusion criteria and selected 73 articles for full-text review. In the end, we included 14 studies in the review. Figure 1 summarizes the literature search and reasons for exclusion of full-text articles.

Study characteristics

Of the 14 studies that met inclusion criteria, one was conducted in Africa,[8] 6 in Asia,[5,7,9,10,16,18] and 6 in Europe,[6,11-13,15,17] and one multinational trial recruited patients in Switzerland and the United States.[14] Seven of the 14 included studies were RCTs whereas the other 7 were observational cohort studies. Most studies (13 of 14) analyzed fractures only of the fifth metacarpal; the other included patients with any metacarpal neck fracture. A total of 704 patients were included across all studies. In terms of patient demographics, average age of patients was 22 to 36 years and patients were predominately male; proportions ranged from 63% to 100% across the included studies.

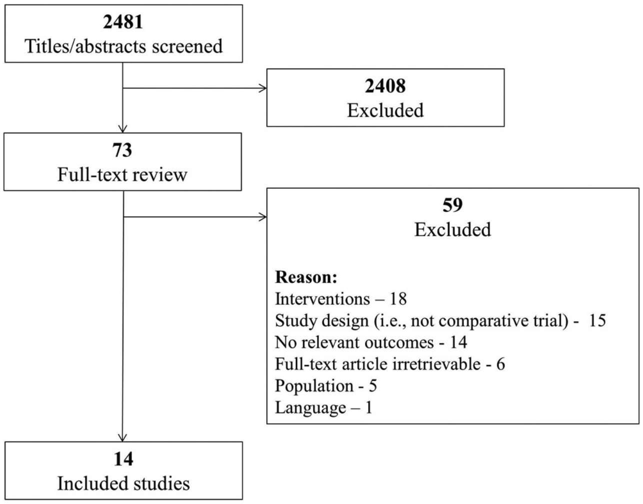

Figure 1. Flow diagram of included studies.

For patient-reported pain and function, we were able to categorize follow-up data within visit windows: early (3 months and less) and later (greater than 3 months). Appendix C (available on the Journal's Web site at www.jhandsurg.org) presents the characteristics of each included study.

Outcome analysis

Pain (scale of 0–100)

Pain scores at 3 months and less were available for comparison via an NMA among AIMP, FB, and RIMP (86 patients). We found the lowest average pain scores with AIMP, but no comparisons were statistically significant (global I^2 = 100%) (Table 1, Fig 2A). Antegrade intramedullary pinning was ranked highest in reducing pain, followed by FB and then RIMP.

In one study comparing BS and SC (39 patients),[14] we found a mean difference in pain scores in favor of BS at 4 months, but this was not statistically significant.

In the NMA among AIMP, FB, plating, RCP, RIMP, and TP within this time frame, there were also no significant differences in pain scores between comparisons (269 patients; global I^2 = 0%) (Table 1, Fig. 2B). Again, AIMP was ranked highest in reducing pain, followed by TP, plating, FB, RIMP, and RCP.

Function (scale of 0–100)

In the NMA of functional scores at follow-up of 3 months or less, we found no statistically significant differences among AIMP, FB, RIMP, or SC (110 patients; global I^2 = 100%), but patients treated with AIMP had the highest scores (Table 1, Fig. 3A). Antegrade intramedullary pinning was ranked highest in improving function, followed by RIMP, FB, and SC.

In the NMA of functional scores greater than 3 months of follow-up, we found no statistically significant differences among AIMP, BS, FB, plating, RCP, RCP-P, RIMP, SC, and TP (481 patients; global I^2 = 84%) (Table 1, Fig 3B). Buddy strapping was ranked highest in improving function, and then FB, RCP-P, TP, SC, AIMP, RIMP, RCP, and plating.

Return to work or regular activities (in weeks)

The NMA of time to return to work or regular activities included AIMP, BS, FB, plating, SC, and TP (314 patients). Although BS demonstrated the earliest return to work and activities, we found no statistically significant differences among any pairwise comparisons (global I^2 = 99.7%) (Table 1, Fig. 4). Buddy strapping was ranked highest in providing earlier return to work or regular activities, followed by FB, SC, plating, TP, and AIMP.

Time to union (in weeks)

In the NMA of time to radiographic or clinical union among AIMP, plating, and TP, we found no significant differences between treatments (149 patients; global I^2 = 0%) (Table 1, Fig. 5). Plating was ranked highest in terms of an earlier time to union, followed by AIMP and then TP.

Delayed union

The NMA of delayed union among AIMP, TP, and plating had some statistically significant findings (94 patients). There was a significantly lower risk for developing a delayed union with TP compared with both AIMP and plating (global I^2 = 0%) (Table 1, Fig. 6). Transverse pinning was ranked highest in having the least risk for a delayed union, followed by AIMP and plating.

Implant migration

Antegrade intramedullary pinning demonstrated a significantly higher risk for implant migration compared with plating and TP (213 patients; global I^2 =0%), whereas there were no statistically significant differences among the other treatments included in the network (Table 1, Fig. 7). Transverse pinning was ranked highest in having the least risk for implant migration, followed by plating and AIMP.

Neurological event

The incidence of a neurological event was also significantly higher with AIMP relative to both plating and TP (98 patients; global I^2 =100%), but we saw no difference between plating and TP (Table 1; Fig. 8). Plating was ranked highest in having the least risk for a neurological event, followed by TP and AIMP.

Study quality

Table 2 lists the results of the study quality assessment. As stated earlier, half of the included studies were RCTs. Three studies had less than 80% follow-up, whereas this was unclear for another 3 studies. In one study, it was unclear whether patient demographics were similar among groups. Finally, the greatest concern was that only one study showed equivalency of outcome measures at baseline among groups, although this was not reported in the other trials.

Discussion

Main findings

This analysis of various interventions for managing metacarpal neck fractures revealed 2 key findings. First, the time frame within which the patient desires symptomatic relief can have an important role in selecting the optimal treatment option. For example, although the result for patient-reported short-term pain was greatly unfavorable for RIMP (in terms of point estimates, not statistical significance) compared with AIMP (MD = 17.37 [95% CrI, −6.34 to 41.09]) and FB (MD = 16.94 [95% CrI, −15.77 to 50.09]), these differences did not contrast as strongly between interventions analyzed at later follow-up. Similarly, although results for patient-reported short-term function greatly favored (again, in terms of point estimates) AIMP and RIMP over each of FB and SC, we found that these differences at later follow-up were less extreme. The return to work and activities data may have conflicted with patient-reported function because conservative options (ie, BS, FB,

Table 1
Effect Estimates for All Pairwise Comparisons

Outcome	Comparison	MD or RR (95% CrI)
Pain, 0–100 (≤ 3 mo)	AIMP vs FB	MD = −0.41 (−22.98 to 21.95)
	AIMP vs RIMP	MD = −17.37 (−41.09 to 6.34)
	FB vs RIMP	MD = −16.94 (−50.09 to 15.77)
Pain, 0–100 > 3 mo	AIMP vs FB	MD = −0.71 (−6.79 to 5.32)
	AIMP vs plating	MD = −0.51 (−5.59 to 4.57)
	AIMP vs RCP	MD = −5.72 (−14.89 to 3.45)
	AIMP vs RIMP	MD = −2.50 (−9.05 to 4.11)
	AIMP vs TP	MD = −0.29 (−4.82 to 4.59)
	FB vs plating	MD = 0.20 (−7.51 to 8.08)
	FB vs RCP	MD = −5.01 (−15.69 to 5.99)
	FB vs RIMP	MD = −1.77 (−10.57 to 7.18)
	FB vs TP	MD = 0.43 (−6.99 to 8.25)
	Plating vs RCP	MD = −5.24 (−15.63 to 5.43)
	Plating vs RIMP	MD = −1.97 (−10.28 to 6.27)
	Plating vs TP	MD = 0.25 (−5.66 to 6.33)
	RCP vs RIMP	MD = 3.23 (−8.03 to 14.32)
	RCP vs TP	MD = 5.44 (−4.78 to 15.81)
	RIMP vs TP	MD = 2.19 (−5.71 to 10.36)
Function, 0–100 ≤ 3 mo	AIMP vs FB	MD = 36.10 (−33.02 to 104.46)
	AIMP vs RIMP	MD = 6.19 (−42.64 to 54.80)
	AIMP vs SC	MD = 38.64 (−10.15 to 87.83)
	FB vs RIMP	MD = −29.91 (−115.55 to 53.80)
	FB vs SC	MD = 2.54 (−45.90 to 50.81)
	RIMP vs SC	MD = 32.37 (−35.57 to 102.76)
Function, 0–100 > 3 mo	AIMP vs BS	MD = −3.97 (−19.97 to 12.00)
	AIMP vs FB	MD = −4.54 (−32.28 to 23.38)
	AIMP vs plating	MD = 6.77 (−4.39 to 17.59)
	AIMP vs RCP	MD = 5.57 (−11.56 to 22.71)
	AIMP vs RCP-P	MD = −3.36 (−22.61 to 15.92)
	AIMP vs RIMP	MD = 1.54 (−14.06 to 17.22)
	AIMP vs SC	MD = −2.16 (−24.96 to 20.39)
	AIMP vs TP	MD = −1.35 (−12.57 to 9.80)
	BS vs FB	MD = −0.60 (−23.22 to 22.38)
	BS vs plating	MD = 10.73 (−8.88 to 30.07)
	BS vs RCP	MD = 9.47 (−13.62 to 32.95)
	BS vs RCP-P	MD = 0.66 (−24.35 to 25.68)
	BS vs RIMP	MD = 5.48 (−16.78 to 27.88)
	BS vs SC	MD = 1.82 (−14.16 to 17.71)
	BS vs TP	MD = 2.69 (−17.12 to 22.08)
	FB vs plating	MD = 11.33 (−18.86 to 41.06)
	FB vs RCP	MD = 9.98 (−22.20 to 42.79)
	FB vs RCP-P	MD = 1.19 (−33.07 to 35.11)
	FB vs RIMP	MD = 6.02 (−26.09 to 38.10)
	FB vs SC	MD = 2.38 (−14.03 to 18.57)
	FB vs TP	MD = 3.17 (−27.38 to 33.10)
	Plating vs RCP	MD = −1.17 (−21.48 to 19.34)
	Plating vs RCP-P	MD = −10.11 (−25.74 to 5.81)
	Plating vs RIMP	MD = −5.25 (−24.32 to 14.23)
	Plating vs SC	MD = −8.91 (−34.12 to 16.36)
	Plating vs TP	MD = −8.09 (−21.25 to 5.19)
	RCP vs RCP-P	MD = −8.87 (−34.68 to 16.76)
	RCP vs RIMP	MD = −4.05 (−27.13 to 19.07)
	RCP vs SC	MD = −7.62 (−36.22 to 20.42)
	RCP vs TP	MD = −6.94 (−27.40 to 13.35)
	RCP-P vs RIMP	MD = 4.83 (−19.87 to 29.57)
	RCP-P vs SC	MD = 1.15 (−28.94 to 30.91)
	RCP-P vs TP	MD = 1.97 (−18.73 to 22.54)
	RIMP vs SC	MD = −3.61 (−31.44 to 23.52)
	RIMP vs TP	MD = −2.87 (−22.25 to 16.29)
	SC vs TP	MD = 0.85 (−24.76 to 25.86)
Time to return to work or regular activities, wk	AIMP vs BS	MD = 8.16 (−5.40 to 22.59)
	AIMP vs TP	MD = −0.06 (−11.48 to 11.70)
	AIMP vs FB	MD = 1.20 (−15.74 to 17.80)
	AIMP vs plating	MD = 0.70 (−10.97 to 12.48)
	AIMP vs SC	MD = 1.14 (−12.47 to 15.08)
	BS vs FB	MD = −6.91 (−29.20 to 14.20)
	BS vs plating	MD = −7.44 (−26.12 to 10.42)
	BS vs SC	MD = −7.02 (−21.16 to 6.73)
	BS vs TP	MD = −8.22 (−26.58 to 9.55)
	FB vs plating	MD = −0.46 (−20.74 to 20.14)
	FB vs SC	MD = −0.07 (−21.49 to 21.68)
	FB vs TP	MD = −1.28 (−21.71 to 19.39)
	Plating vs SC	MD = 0.44 (−17.59 to 18.64)

Table 1 (*continued*)

Outcome	Comparison	MD or RR (95% CrI)
	Plating vs TP	MD = −0.75 (−14.68 to 13.11)
	SC vs TP	MD = −1.20 (−19.17 to 16.91)
Time to clinical or radiographic union, wk	AIMP vs plating	MD = 1.28 (−0.77 to 3.36)
	AIMP vs TP	MD = −0.06 (−1.25 to 1.14)
	Plating vs TP	MD = −1.34 (−3.71 to 1.02)
Risk for delayed union	TP vs AIMP*	RR = 0.00 (0.00 to 0.76)
	Plating vs AIMP	RR = 2.69 (0.32 to 31.8)
	TP vs plating*	RR = 0.00 (0.00 to 0.26)
Risk for implant migration	Plating vs AIMP*	RR = 0.00 (0.00 to 0.06)
	TP vs AIMP*	RR = 0.00 (0.00 to 0.03)
	Plating vs TP	RR = 6.30 (0.00 to 1.44×10^{21})
Risk for neurological event	Plating vs AIMP*	RR = 0.00 (0.00 to 0.14)
	TP vs AIMP*	RR = 0.00 (0.00 to 0.17)
	Plating vs TP	RR = 0.34 (0.00 to 3.81×10^{20})

RR, risk ratio.
* Statistically significant.

and SC) seemed to perform more favorably than operative approaches in terms of return to work and activities; however, we believe that in addition to the limited evidence on this topic, that surgical interventions also require a postoperative recovery and rehabilitation period would explain this finding. In other words, although patients treated conservatively may return to work and regular activities earlier than those treated operatively, it does not necessarily mean that they also have better functional outcomes. Therefore, the results suggested that AIMP may confer the most effective management for both pain and function in the short term, whereas differences between interventions at later follow-up contrasted less strongly. However, there were no efficacy data with regard to BS, plating, RCP, RCP-P, or TP for both short-term pain and function. Time to clinical or radiographic union was most favorable with plating compared with both AIMP and TP, although this was not statistically significant.

Second, the analysis of safety data indicated significantly higher risks of certain complications with AIMP compared with other interventions. Patients who received AIMP had significantly higher risks compared with those who received plating of implant migration and neurological events. For the risk for delayed union, patients who received AIMP had a significantly higher risk compared with patients who received TP. Risk ratios were not statistically significant between plating and TP for implant migration and neurological events; TP had a significantly lower risk for delayed union compared with plating. These results suggest an unfavorable safety profile for AIMP; however, these analyses were limited by small sample sizes and low event rates.

Another factor to consider is that postintervention protocols were not absolutely consistent across studies. There is no standardization regarding whether immobilization should be prescribed after treatment, and if so, how for long. In cases in which an orthosis or cast is applied, alone or in addition to another therapy, immediate mobilization is not possible. In studies in which immobilization was prescribed, this period ranged from 1 to 6 weeks. Physiotherapy and rehabilitation protocols were also inconsistent across studies. In some cases, rehabilitation was prescribed only when deemed necessary; in other cases, all patients attended a set number of physiotherapy sessions. Such considerations are important to consider, to evaluate to what extent they may affect patient outcomes and the interpretation of study results.

Previous literature

Our findings are consistent with a previous systematic review conducted by Corkum et al,[19] in which intramedullary fixation demonstrated greater functional improvements in the short term compared with other techniques. In addition, we were able to demonstrate that this advantage may not be present at longer-term follow-up, which provides more insight into the therapeutic trajectory of these interventions. We also compared intramedullary pinning with nonsurgical methods, which was a need explicitly stated in the report of Corkum et al. Moreover, although the results were not statistically significant, the effect estimates suggested more favorable pain reduction and functional improvement with AIMP in the short term (3 months or less), whereas differences among interventions at later follow-up were less extreme.

Another meta-analysis by Zong et al[20] confirmed the higher risk for complications with AIMP (although they did not specify which complications) and recommended conservative treatment owing to a lower complication rate. However, with respect to surgical treatments, the authors considered both plating and AIMP to be first-line options given their similar safety profiles. Our study further demonstrated that AIMP conferred significantly higher risks of implant migration and neurological events compared with plating. As such, plating may provide a more preferable safety profile than AIMP. Nevertheless, AIMP may still be considered a viable option owing to its efficacy in the short term, which could be beneficial for patients desiring rapid relief.

Intramedullary pinning's therapeutic trajectory, which entails a more rapid short-term functional improvement and a high risk for long-term complications, could be explained by its biological basis. In particular, Chin et al[24] found that intramedullary pinning does not provide a rigid fixation and the pins are left outside the skin, both of which could explain its higher likelihood of complications. Also, it requires a longer period of immobilization and has a lower resistance to angulation and rotational forces, which poses a threat to its long-term effectiveness; similar disadvantages are also seen with TP.[25] In comparison, although it requires more invasive soft tissue dissection, plating offers a relatively more rigid fixation to ensure sufficient healing for the initiation of motion.[25,26]

Strength and limitations

Our study offers several strengths in contributing to the current pool of evidence on metacarpal neck fracture management. First, the study used a network meta-analysis to compare different interventions simultaneously. Relative to the recent systematic review and NMA by Zong et al,[20] our review was different because it (1) included an additional 8 studies, 6 of which were published since 2015; (2) added RIMP and RCP with or without plating to the network and distinguished among 3 different conservative options; and (3) evaluated patient-important outcomes (ie, pain, function, and return to work or regular activities) and the relative risk for

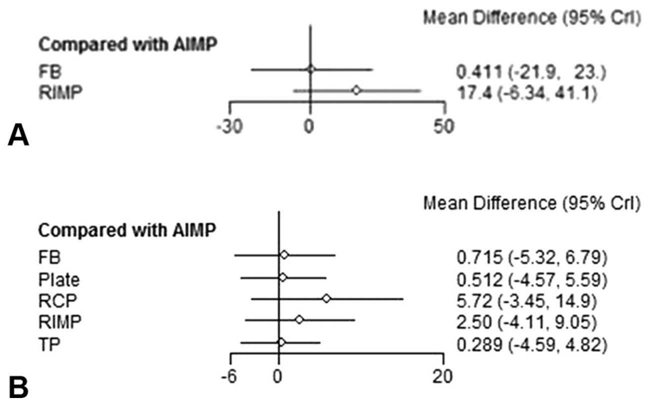

Figure 2. Mean differences in pain scores (scale of 0–100; lower scores represent less pain) between **A** AIMP, FB, and RIMP at 3 months or less; and **B** AIMP, FB, plating, RCP, RIMP, and TP at greater than 3 months.

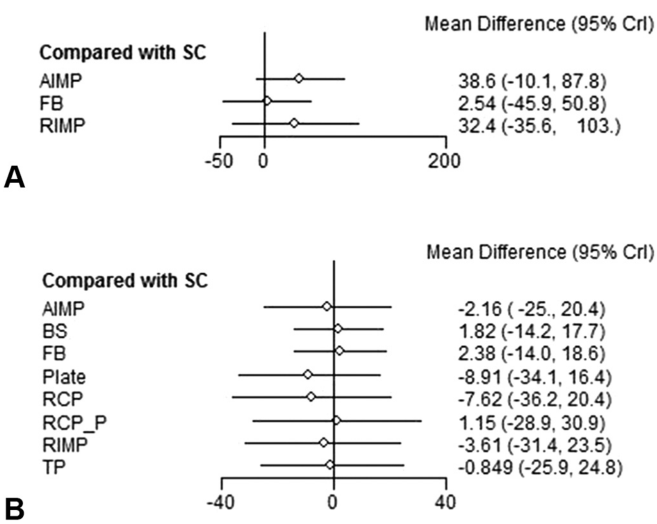

Figure 3. Mean differences in functional scores (scale of 0–100; higher scores represent improved function) between **A** AIMP, FB, RIMP, and SC at 3 months or less; and **B** AIMP, BS, FB, plating, RCP, RCP-P, RIMP, TP, and SC at greater than 3 months.

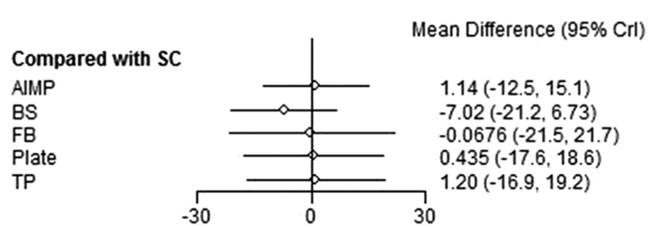

Figure 4. Mean differences in time to return to work or regular activities (measured in weeks) among AIMP, BS, FB, plating, SC, and TP.

specific complications. This provides in-depth insights on all therapeutic options and offers a comprehensive assessment for clinicians who wish to explore a specific technique and how it compares with treatment options. Finally, we categorized the efficacy analyses into different durations of follow-up. Effectiveness of, or preference for, an intervention may hinge on the time frame for which it is considered, because we observed a potential trade-off between faster recovery and long-term stability; therefore, our results can be valuable to inform clinicians interested in symptomatic relief across specific time frames.

Limitations of this study included the low precision in our estimates and the lack of high-quality primary research (ie, limited RCT evidence). Although we included 14 articles, not all studies reported on each outcome evaluated in our review; because of this, only some of the investigated treatments could be included in a given analysis in some cases. As such, the precision of our results was low, as demonstrated by the wide precision intervals. In addition, in some instances, we could not compare certain treatments for a given outcome. Also, TP techniques can be either blocked (pins are connected externally) or unblocked, and we grouped them together as one treatment node; we decided that there was insufficient evidence to examine these as separate interventions. Only 7 of the 14 included articles were RCTs, which conferred a higher risk for bias. This also emphasizes the need for large-scale RCTs in the future. Nevertheless, despite these shortcomings, we believe that the data provide some insights into the pros and cons of these different treatments in managing metacarpal fractures. The inclusion of high-quality trials reporting on these outcomes would result in more precise effect estimates and allow us to make more definitive conclusions regarding these results.

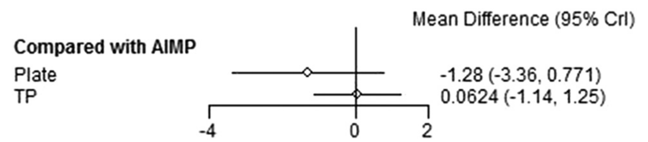

Figure 5. Mean differences in time to clinical or radiographic union (measured in weeks) among AIMP, plating, and TP

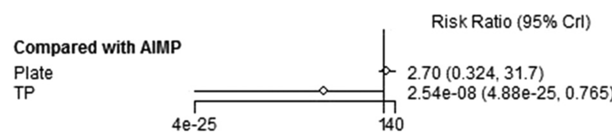

Figure 6. Relative risk for delayed union among AIMP, TP, and plating.

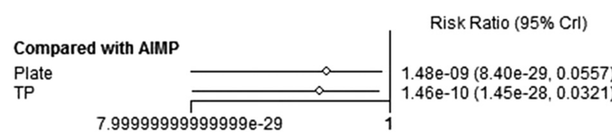

Figure 7. Relative risk for implant migration among AIMP, plating, and TP.

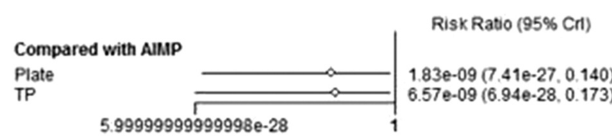

Figure 8. Relative risk for neurological event among AIMP, plating, and TP.

This systematic review and meta-analysis demonstrated that although AIMP may be a preferable management option for short-term improvements in pain and function, it may also be associated with a high risk for certain postoperative complications that are less likely to occur with other surgical options. There were no data on how some interventions (ie, BS, plating, RCP, RCP-P, or TP) perform in the short-term, so it is unclear how beneficial they might be within this earlier visit window. Clinicians should account for patient preferences for the time frame of symptomatic relief when selecting the optimal therapeutic option, and patients should weigh the risks and benefits of each available treatment, especially

Table 2
Study Quality Assessment

Study, date	Design	Cohort	Control or Comparison Group	Pre-Post Intervention Data	Random Assignment	Random Selection	Follow-Up Rate ≥ 80%	Equivalent Demographics	Equivalent at Baseline on Outcome Measures
Cepni et al, 2016	RCT	Yes	Yes	Yes	Yes	Yes	Yes	NR	NR
Facca et al, 2010	Obs.	Yes	Yes	Yes	No	Yes	Yes	Yes	NR
Fujitani et al, 2012	Obs.	Yes	Yes	Yes	No	Yes	Yes	Yes	NR
Galal and Safwat, 2017	RCT	Yes	Yes	Yes	Yes	Yes	No	Yes	NR
Kaynak et al, 2019	Obs.	Yes	Yes	Yes	No	Yes	No	Yes	NR
Kim and Kim, 2015	RCT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NR
Schadel-Hopfner et al, 2007	Obs.	Yes	Yes	Yes	No	Yes	Yes	Yes	NR
Sletten et al, 2015	RCT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NR
Strub et al, 2010	RCT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NR
van Aaken et al, 2016	RCT	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Winter et al, 2007	RCT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NR
Wong et al, 2006	Obs.	Yes	Yes	Yes	No	Yes	NR	Yes	NR
Zemirline et al, 2014	Obs.	Yes	Yes	Yes	No	Yes	NR	Yes	NR
Zhu et al, 2017	Obs.	Yes	Yes	Yes	No	Yes	NR	Yes	NR

NR, not reported; Obs., observational cohort.

with more invasive surgical interventions. Considering the lack of high-quality primary research investigating these management options for metacarpal neck fractures, future studies might include more large-scale, multicentered, randomized trials to inform the best standard of practice and provide data that will result in more definitive conclusions.

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Appendix A. Search Strategies for MEDLINE, EMBASE, and Cochrane Library databases

MEDLINE

1. Metacarpal Bones/
2. (metacarpal or meta-carpal or hand).ti,ab.
3. (fracture* or injur* or broke* or break).ti,ab.
4. (1 or 2) and 3
5. exp Fracture Fixation/
6. (((intramedul* or inter?locking or IM) adj4 (nail* or rod* or screw*)) or IMN or AIMN).ti,ab.

7. (k-wire* or kwire* or k wire or (kirschner adj4 wire*)).ti,ab.
8. exp closed fracture reduction/
9. exp open fracture reduction/
10. (((open or close) adj3 (reduction or fixation)) or ORIF).ti,ab.
11. plate*.ti,ab.
12. pin*.ti,ab.
13. screw*.ti,ab.
14. (conservative* or nonsurgical* or non-surgical* or non-operative* or non-operative*).ti,ab.
15. exp Conservative Treatment/
16. or/5-15
17. exp Clinical Study/
18. exp Clinical Studies as Topic/
19. Comparative Effectiveness Research/
20. Comparative Study/
21. Multicenter Study/
22. Cohort Studies/
23. (random* or RCT or cohort* or comparative or clinical study or clinical trial or controlled trial).ti,ab.
24. exp Animals/
25. Humans/
26. 24 not 25
27. Case reports/
28. (case report* or case study).ti.
29. 17 or 18 or 19 or 20 or 21 or 22 or 23
30. 29 not (26 or 27 or 28)
31. 4 and 16 and 30

EMBASE

1. metacarpal.mp.
2. Metacarpal Bones/
3. fracture.mp.
4. (1 or 2) and 3
5. ((metacarp* and (fractur* or bone fractur* or digit fractur*)) or ((open or closed or intra?articular or extra?articular or transverse or oblique or spiral or comminuted or impacted or avulsion) and metacarp*) or (fractur* or bone fractur* or digit fractur*) or (metacarp* and (head or neck or shaft) and (fractur* or bone fractur* or digit fractur*)) or ((index or middle or ring) and metacarp* and (fractur* or bone fractur* or digit fractur*))).ti,ab.
6. 4 or 5
7. exp Fracture Fixation, Intramedullary/
8. intramedullary nail.mp.
9. (((intramedul* or inter?locking or IM) adj4 (nail* or rod* or screw*)) or IMN or AIMN).mp.
10. (k-wire* or K-wire* or (kirschner adj4 wire*)).mp.
11. exp closed fracture reduction/
12. exp open fracture reduction/
13. ((open or close) adj3 (reduction or reduction fixation or internal fixation or plate fixation or fixation)).ti,ab.
14. (transverse pin* or TP).ti,ab.
15. ((screw* adj3 fixation*) or (compression* adj3 screw*) or (headless adj3 screw*)).mp.
16. conservative treatment.mp. or ((nonsurgical* or non-surgical* or nonoperative* or non-operative*) adj3 (procedure* or manag* or treat*)).ti,ab.
17. exp Conservative Treatment/
18. 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19. exp Clinical Study/
20. exp Clinical Studies as Topic/
21. Comparative Effectiveness Research/
22. Comparative Study/
23. Multicenter Study/
24. Cohort Studies/
25. (random* or RCT or cohort* or comparative or clinical study or clinical trial or controlled trial).ti,ab.
26. exp Animals/
27. Humans/
28. 26 not 27
29. Case reports/
30. (case report* or case study).ti.
31. 19 or 20 or 21 or 22 or 23 or 24 or 25
32. 31 not (28 or 29 or 30)
33. 6 and 18 and 32
34. limit 33 to english

Cochrane

#1 (metacarpal):ti,ab,kw OR (Metacarpal Bones):kw
#2 ((metacarp* and (fractur* or bone fractur* or digit fractur*)) or (((open or closed or intra?articular or extra?articular or transverse or oblique or spiral or comminuted or impacted or avulsion) and metacarp*) or (fractur* or bone fractur* or digit fractur*)) or (metacarp* and (head or neck or shaft) and (fractur* or bone fractur* or digit fractur*))).mp. or ((index or middle or ring) and metacarp* and (fractur* or bone fractur* or digit fractur*)):ti,ab
#3 #2 or #1
#4 MeSH descriptor: [Fracture Fixation] explode all trees
#5 (Intramedullary):kw OR (intramedullary nail):ti,ab,kw
#6 (((intramedul* or inter?locking or IM) adj4 (nail* or rod* or screw*)) or IMN or AIMN):ti,ab,kw
#7 (k-wire*):ti,ab,kw OR (K-wire*):ti,ab,kw AND (kirschner adj4 wire*):ti,ab,kw
#8 MeSH descriptor: [Closed Fracture Reduction] explode all trees
#9 MeSH descriptor: [Open Fracture Reduction] explode all trees
#10 ((open or close) adj3 (reduction or reduction fixation or internal fixation or plate fixation or fixation)):ti,ab,kw
#11 (conservative treatment):ti,ab,kw OR (nonsurgical):ti,ab,kw OR (non-surgical):ti,ab,kw OR (nonoperative):ti,ab,kw OR (non-operative):ti,ab,kw
#12 MeSH descriptor: [Conservative Treatment] explode all trees
#13 (transverse pin*):ti,ab,kw OR (TP):ti,ab,kw
#14 #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13
#15 #3 and #14
#16 #15 in Trials

Appendix B
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Metacarpal fracture of any digit	Study focused on pediatric or adolescent patient population
Skeletally mature patients	Case series, case reports, case-control trials
RCT or observational comparative studies (prospective or retrospective)	Study not published in English or conference abstracts
Compared at least 2 different treatments for metacarpal fractures	
Study published in English	
Full text available	

Appendix C
Characteristics of Included Studies

Author, Year	Location of Study	Study Design	Fracture Location	Sample Size	Treatments Evaluated	Length of Study Follow-Up	Age, y	Gender (% Male)
Cepni et al, 2016	Turkey	Randomized trial	Fifth MC; neck fracture	24	AIMP	45 d	Mean: 28 (range, 18–46)	100
					Placement of orthosis		Mean: 28 (range, 18–46)	100
Facca et al, 2010	France	Observational cohort	Fifth MC; neck fracture	38	AIMP	Mean: 3 mo (range, 2–14 mo)	Mean: 35 (range, 18–73)	85
					Plating	Mean: 5 mo (range, 2–14 mo)	Mean: 30 (range, 18–53)	94
Fujitani et al, 2012	Japan	Observational cohort	Any MC; neck fracture	30	AIMP	12 mo	Mean: 28 (range, 16–59)	87
					Plating		Mean: 33 (range, 17–53)	87
Galal and Safwat, 2017	Egypt	Randomized trial	Fifth MC; neck fracture	60	AIMP	12 mo	Mean: 32	NR
					TP		Mean: 32	NR
Kaynak et al, 2019	Turkey	Observational cohort	Fifth MC; neck fracture	40	Placement of orthosis	6 mo	Mean: 28 (range, 18–58)	94
					Functional bracing		Mean: 30 (range, 18–43)	100
Kim and Kim, 2015	South Korea	Randomized trial	Fifth MC; neck fracture	46	AIMP	6 mo	Mean: 31 (range, 18–53)	100
					RIMP		Mean: 32 (range, 19–54)	100
Schadel-Hopfner et al, 2007	Germany	Observational cohort	Fifth MC; neck fracture	30	AIMP	Median: 17 mo (range, 6–34 mo)	Median: 26 (range, 15–46)	100
					Retrograde cross-pinning	Median: 18 mo (range, 12–41 mo)	Median: 25 (range, 16–52)	93
Sletten et al, 2015	Norway	Randomized trial	Fifth MC; neck fracture	81	AIMP	12 mo	Median: 25 (range, 18–68)	92
					BS		Median: 29 (range, 18–67)	91
Strub et al, 2010	Switzerland	Randomized trial	Fifth MC; neck fracture	40	AIMP	12 mo	Mean: 28 (range, 20–44)	95
					FB		Mean: 32 (range, 21–70)	90
van Aaken et al, 2016	Switzerland and United States	Randomized trial	Fifth MC; neck fracture	68	BS	4 mo	Mean: 30	97
					Casting		Mean: 27	96
Winter et al, 2007	France	Randomized trial	Fifth MC; neck fracture	36	AIMP	90 d	Mean: 31 (range, 18–65)	NR
					TP		Mean: 32 (range, 20–49)	NR
Wong et al, 2006	China	Observational cohort	Fifth MC; neck fracture	59	AIMP	Mean: 24 mo (range, 12–36 mo)	Mean: 22 (range, 15–35)	90
					TP		Mean: 23 (range, 14–30)	93
Zemirline et al, 2014	France	Observational cohort	Fifth MC; neck fracture	56	AIMP	Mean: 3 mo	Mean: 34 (range, 18–73)	85
					Plating	Mean: 5 mo	Mean: 30 (range, 18–53)	94
					Blocked TP	Mean: 3 mo	Mean: 24 (range, 13–52)	83
Zhu et al, 2017	China	Observational cohort	Fifth MC; neck fracture	96	Plating	12 mo	Mean: 36	63
					Retrograde cross-pinning and plating		Mean: 36	64

IM, intramedullary; MC, metacarpal; NR, not reported.