

Review

Cortical versus cancellous screws in treating medial malleolar fractures: A systematic review of comparative clinical and biomechanical studies

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ABSTRACT

Study design: Systematic review of comparative studies.

Background: Partially threaded (PT) cancellous screws are a common method to fix medial malleolar fractures but with reported complications due to the hardware. Fully threaded (FT) screws have been advanced as an alternative yielding similar union results with less implant-related complications.

Objectives: The aim of this study is to systematically collate comparative clinical and biomechanical evidence on the effectiveness and complications of the PT versus FT screw constructs in the treatment of medial malleolar fractures.

Results: Based on 7 studies (8 subgroups), similar weighted healing rates were found from pooling 3 clinical studies with the time to heal outcome significantly shorter following FT compared to PT screws. Complication rates in the form of screw loosening (1.97% vs. 13.4%, $p = 0.008$) and screw removal surgery (0% vs. 15.7%, $p < 0.0001$) were significantly higher after using PT screws. The five biomechanical studies demonstrated that FT screw constructs had significantly superior properties than the PT constructs and that for all outcomes.

Conclusion: Fully threaded screws seem to offer significantly better clinical and biomechanical outcomes when compared to the partially threaded screws in treating medial malleolar fractures. The use of headless FT screws could contribute to reduce the implant-related complications.

Level of evidence: Therapy, level 3.

1. Introduction

Ankle fractures are common injuries occurring at an incidence of 187 fractures per 100,000 people in the United States [1]. Isolated fibula fracture (up to 58% of all ankle fractures) if not displaced could be treated conservatively. However, bi-malleolar fractures (27%) and displaced isolated medial malleolar fractures (8%) are usually unstable and surgical stabilization is usually required [2].

For the fractures of the medial malleola (FMM), a wide variety of constructs have been reported. The commonest internal fixation methods include tension band wiring and the partially threaded (PT) cancellous lag screws [3,4]. However, persistent ankle symptoms related to painful implants is not uncommon [5–7]. Ankle implants could cause pain and reoperation for implant removal is sometimes required [8]. This has been reported as a classical complication following the use of PT cancellous screws that have loosened and backed out [8,9]. To

this, some authors tested the use of fully threaded (FT) cortical screws for the treatment of FMM. Their findings showed that FT screws offer similar clinical results with less complication rates when compared to PT constructs [10–12]. In addition, biomechanical testing of FT screws seem to offer better properties when compared to PT screws [10]. However, implant loosening does not necessarily lead to non-union or to revision for removal in clinical settings.

To our knowledge, no evidence synthesis has been published in the literature to support these claims. Therefore, the aim of this study is to systematically collate comparative clinical and biomechanical evidence on the effectiveness and complications of the PT versus FT screw constructs in the treatment of medial malleolar fractures.

2. Methods

This review followed the PRISMA (Preferred Reporting Items for

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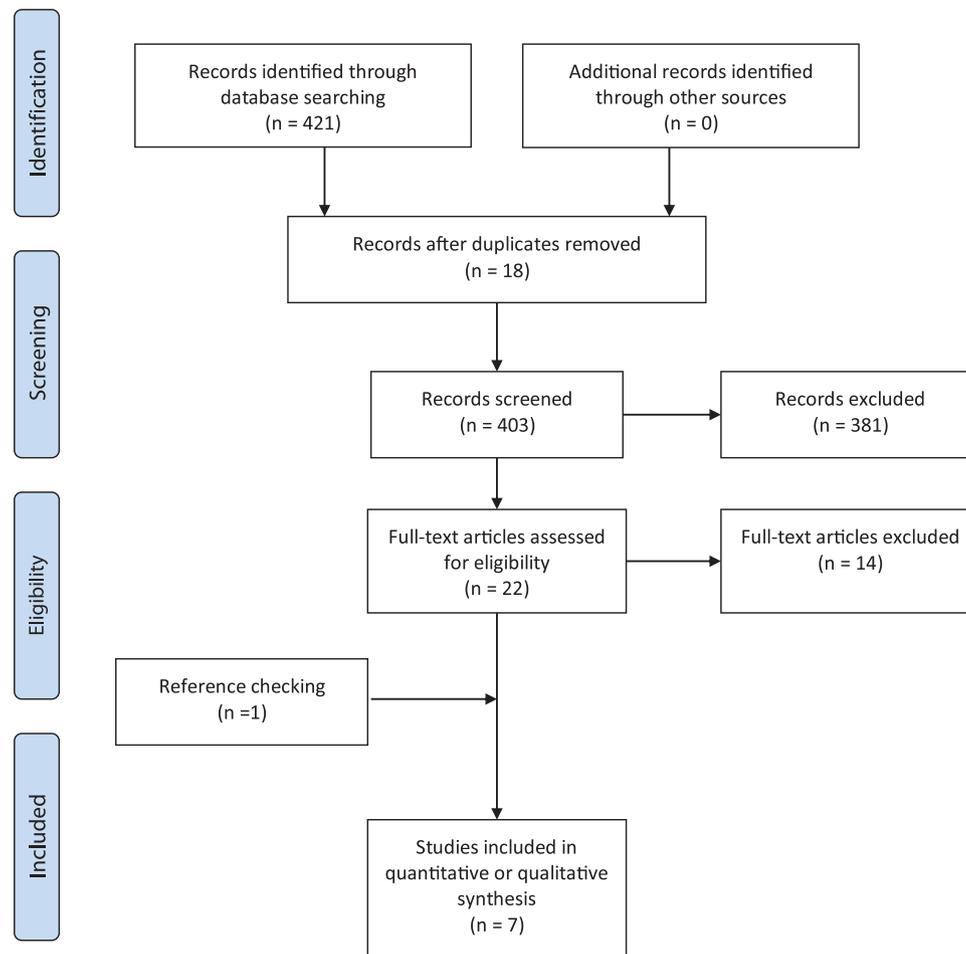


Fig. 1. PRISMA flowchart.

Systematic Reviews and Meta-Analyses) guidelines [13].

2.1. Search strategy

An electronic search literature was developed using the following databases from inception to October 2018: Medline, EMBASE, Scopus, and Google Scholar. Broad Boolean terms were chosen and combined to locate the maximum number of relevant studies: “medial malleol* fracture*” AND screw*.

2.2. Study inclusion and exclusion criteria

Only comparative clinical or biomechanical studies were included. Interventions comprise comparison of any type of fully threaded screws to any type of partially threaded screws. In clinical studies, isolated and non-isolated FMM such as bi-malleolar or trimalleolar fractures were included. Case-series, case reports or reviews were excluded. Only adult population was included (age > 18 years). For the biomechanical studies, cadaveric and studies using fourth generation sawbones or those with at least 15 pounds per cubic foot (PCF) density were accepted for inclusion. All types of clinical or biomechanical outcomes reported in the included studies were investigated.

2.3. Outcome definition

The primary clinical outcomes were defined as the non-union, screw loosening and implant-related revision rates. Secondary clinical outcomes were set as infection rate and the mean healing time. For the biomechanical studies, all outcomes were recorded since we anticipated

non-homogenous outcome reporting from the included biomechanical studies.

2.4. Quality appraisal

The quality of the clinical studies was assessed by the Joanna Briggs Institute (JBI) tool checklist [14]. Two reviewers (K.Y., C.A.) conducted quality analysis. In case of disagreement, it was resolved by open discussion.

2.5. Statistical analysis

The software StatsDirect was used for analysis. Analyses were performed separately for 3 subgroups: clinical, cadaveric and sawbones. Whenever possible, a meta-analysis (MA) was conducted to generate weighted estimates. Heterogeneity was assessed using I^2 inconsistency test. Whenever, I^2 value was less than 50%, the fixed-effects model value was stated, otherwise, the random-effects model value was reported. Significance was set for p-values of < 0.05. When MA was not feasible, a narrative description of the results of each individual study was reported.

3. Results

3.1. Search results

The electronic search yielded 421 hits records. After title and abstract screening, 22 studies were found relevant and full manuscript was retrieved. Six studies met the inclusion criteria. Reference checking

Table 1
Characteristics and outcomes of clinical studies.

Study	Type of fixation	Screws dimension	Sample size	Mean age (years)	Study design	Nonunion rate	Mean healing time (months)	Infection	Screw loosening	Removal	Fracture type
Ricci et al. [10]	FT	2*3.5 × 80 mm	46	45 ± 14.7	Retrospective comparative (closed bimalleolar & isolated MM fractures)	0	NR	0	1 (2.2%)	0	OTA 43B
	PT	2*4.0 × 45 mm	46	43 ± 16.5		2 (4.3%)	NR	0	12 (26.1%)	2 (4.3%)	OTA 44B OTA 44C
Bulut et al. [11]	FT	NR (headless)	11	37.64 ± 14.07	Retrospective comparative (isolated MM fractures)	0	8.8 ± 1.7	0	0	0	Herscovici B, C and D
	PT	NR	10	30.4 ± 8.54		0	10 ± 2.8	0	0	2 (20%)	Herscovici B and C
Kochai et al. [12]	FT	NR (headless)	32	37.75 ± 9.75	Retrospective comparative (isolated MM fractures)	0	9 ± 1	0	0	0	Herscovici B and C
	PT	NR	32	36.84 ± 9		0	12 ± 0.5	0	1 (3.1%)	11 (34.3%)	

FT: fully threaded (cortical), PT: partially threaded (cancellous), MM: medial malleolus, OTA: orthopedic trauma association.

yielded another relevant study. In total, 7 studies met the inclusion criteria (10–12, 15–18) including 8 subgroups: 3 clinical and 5 biomechanical (2 cadaveric and 3 using sawbones). Fig. 1 shows details of the search results. The study of Ricci et al. [10] reported both, clinical and cadaveric outcomes.

3.2. Basic characteristics and quality of the clinical studies

The three clinical studies included 177 subjects, 89 and 88 patients were treated with fully and partially threaded screws, respectively (10–12). All studies had a retrospective comparative design. The mean age of their pooled sample was 38.4 ± 4.7 years. All included fractures were equivalent to Weber’s classification B or C. The characteristics and individual outcomes of each clinical study are summarized in Table 1.

All three studies had a JBI quality score of 9 out of a maximum of 10. There was no “No” answers for all studies. The quality of each clinical study is shown in Table 2.

3.3. Meta-analytical outcome values of the clinical studies

The non-union rate was 0% for FT screws and 2.9% (95% CI = 0.004–0.072, I2 = 0%) for PT screws. The weighted risk difference was 2.26% (95% CI = -0.071 to 0.025, I2 = 0%) in favor of FT but with no statistical significance (p = 0.3).

Screw loosening rates were of 1.97% (95% CI = 0.001–0.057, I2 = 0%) and 13.4% (95% CI = 0.003–0.298, I2 = 81.7%) for the FT and PT screws, respectively. The weighted RD was of 13.5% (95% CI = -0.214 to -0.056, I2 = 81.8%, p = 0.008) in favor of FT screws.

The implant-related removal rates were of 0% and 15.7% (95% CI = 0.090–0.239, I2 = 84.3%) for the FT and PT screws, respectively. The weighted RD was of 17% (95% CI = -0.251 to -0.089, I2 = 88%, p < 0.0001) in favor of FT screws.

Based on 2 studies (11, 12), the effect size difference for the time to heal variable was of 2.23 months (95% CI = -2.828 to -1.640, p < 0.0001) in favor of FT screws.

The infection rate was 0% for both constructs.

3.4. Characteristics and outcomes of the cadaveric biomechanical studies

Table 3 summarizes the characteristics and individual outcomes of each cadaveric study. Two studies included 16 specimens with equal distribution for both interventions [10,15]. The mean age of the specimens was 72 ± 5 years. Since the outcome variables were dissimilar, no meta-analysis could be conducted.

Ricci et al. [10] calculated the torque reached till screw stripping. The FT lag screw group showed an average maximum torque generation of 64.0 N before screw stripping, 3 times greater than that seen with the PT lag screws (17.8 N) (P < 0.0002).

Pollard et al. [15] investigated the needed strength for a displacement of more than 4 mm at the osteotomy site. The force captured at 2-mm fracture gapping was 327.6 N and 116.2 N for FT versus PT screws, respectively (P = 0.04).

3.5. Outcomes of the sawbones biomechanical studies

Table 4 summarizes the characteristics and individual outcomes of each “sawbones” study. Three studies with a total of 97 sawbones were included [16–18]. Since the outcome variables were dissimilar, no meta-analysis could be conducted.

Fowler et al. [16] studied 3 outcomes (2 mm of displacement, catastrophic failure, and stiffness) with 3 loading mechanism: axial loading, transversal loading and tension loading. No significant differences were found between both methods when using axial loading and that for all 3 outcomes. All other outcomes but one showed significant differences in favor of FT screws for transverse and tension loading mechanisms (p ≤ 0.001); only the stiffness outcome using transverse

Table 2
JBI critical appraisal checklist for case control studies.

Checklist	Ricci et al. [10]	Bulut et al. [11]	Kochai et al. [12]
1 Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?	Yes	Yes	Yes
2 Were cases and controls matched appropriately?	Yes	Yes	Yes
3 Were the same criteria used for identification of cases and controls?	Yes	Yes	Yes
4 Was exposure measured in a standard, valid and reliable way?	Yes	Yes	Yes
5 Was exposure measured in the same way for cases and controls?	Yes	Yes	Yes
6 Were confounding factors identified?	Yes	Yes	Yes
7 Were strategies to deal with confounding factors stated?	Unclear	Unclear	Unclear
8 Were outcomes assessed in a standard, valid and reliable way for cases and controls?	Yes	Yes	Yes
9 Was the exposure period of interest long enough to be meaningful?	Yes	Yes	Yes
10 Was appropriate statistical analysis used?	Yes	Yes	Yes
Total of “No”	0	0	0

JBI: Joanna Briggs Institute.

Table 3
Characteristics and outcomes of cadaveric studies.

Study	Type of fixation	Screw specs	Sample size	Mean age (range)	Stress type	Strength for 2 mm displacement	Torque generation	Fracture type
Ricci et al. [10]	FT	2 (3.5 × 80 mm)	3	65 (63–69)	Torque before screw	NR	64.0 ± 19.6 N	OTA 44 B2.2
	PT	2 (4.0 × 45 mm)	3	65 (63–69)	stripping	NR	17.8 ± 6.2 N	
Pollard et al. [15]	FT	2 (3.5 × 70.0 mm)	5	79 (65–97)	Distraction at osteotomy site 1.0 mm/s	327.6 ± 265.73 N	NR	Muller type B
	PT	2 (4.0 × 40.0 mm)	5	79 (65–97)		116.2 ± 137.91 N	NR	

FT: fully threaded (cortical), PT: partially threaded (cancellous).

loading showed no significance.

Downey et al. [17] showed that the initial construct stiffness was greater with the PT screws ($p = 0.026$). The yield load and displacement were significantly better with FT compared to PT screws ($p < 0.001$) following a shear axial loading mechanism at 0.5 mm/s of displacement rate. The failure strength of FT screws was significantly greater ($p < 0.002$) than that of the FT screws.

Wegner et al. [18] investigated outcomes following an axial loading at 1 mm/s rate up to 6 mm of displacement and cycled back to 0 mm. They demonstrated that the FT screw fixation construct was over 2 times stiffer than the PT one ($P < 0.0001$). The needed strength for 2 mm displacement, defined as clinical failure, showed that FT construct resisted displacement significantly more ($P = 0.0001$) than the PT construct, presenting a 100% increase. When cycling back to 0-mm displacement, PT construct demonstrated no elastic recoil whereas the FT construct rebounded to almost 0-mm displacement.

4. Discussion

To our knowledge, this is the first evidence synthesis comparing fully threaded cortical to partially threaded cancellous screws in fixing medial malleolar fractures. This systematic review demonstrated clinical and biomechanical advantages of the FT over the PT screw constructs.

4.1. Main findings

While the healing rate was better following FT screws in clinical settings, outcome difference was not significant. The time to heal was significantly shorter following FT compared to PT screws. On the other hand, complication rates in the form of screw loosening and screw removal surgery were significantly higher after using PT screws. The five biomechanical studies demonstrated that FT screw constructs had significantly superior properties than the PT constructs and that for all outcomes.

4.2. Interpretation of the results

The lesser complication rate and the better initial stiffness and

resistance to displacement would indicate that FT cortical screws is a better option than PT cancellous screws in treating medial malleolar fractures.

Brown et al. [8] demonstrated that prominent implants such as the cancellous crews could be a source of pain in 31% of patients while 23% either had reoperation for implant removal or desired it removed. Based on our findings, it is better to use FT than PT screws since the rate of loosening, and consequently the re-operation rate, is significantly less. Therefore, minimizing the prominence of the screws would have the potential to improve patient outcomes. In fact, 2 out of 3 clinical studies used FT headless screws. This could be an appropriate solution to reduce screw prominence which is believed to contribute to implant removal rate.

4.3. Limitations

The major limitations of the review are the number of all included studies and the study design of the included clinical studies where all clinical studies were of retrospective design. In addition, some relevant variables were not reported such as the screws' specifications; for instance, Bulut et al. [11] and Kochai et al. [12] failed to mention screws dimensions. As opposed to the two other clinical studies which investigated isolated medial malleolar fractures, the study of Ricci et al. included a number of bimalleolar fractures. These “clinical” limitations are unlikely to have significantly impacted the results of our review. Heterogeneity as shown with the inconsistency I^2 test values could be related to the screw type specification, fracture classification and inclusion of isolated fractures.

On the other hand, cadaveric and sawbones studies were controlled and randomized but small-sampled. Different classifications have been used but all studies included fractures at the level or above the syndesmosis.

Given the limitations of this study, the generalizability of our findings might be suboptimal. Nevertheless, and despite these limitations, all included studies concur to conclude that FT screws yield significantly lesser overall complications and complication-related revision surgery rates.

Table 4
Characteristics and outcomes of sawbones studies.

Study	Sawbones material	Type of fixation	Screw specs	Stress type	Sample size	Initial stiffness	Yield load	Displacement	Strength for 2 mm displacement	Failure strength	Fracture type
Fowler et al. [16]	Sawbones 4 th G	FT	3.5 × 75 mm	Adduction – axial loading	10	126 ± 53 N/mm	-	-	328 ± 78 N	498 ± 147 N	OTA 44–B2.2
				External rotation – transverse loading	10	56 ± 19 N/mm	-	-	190 ± 63 N	462 ± 141 N	
Downey et al. [17]	Sawbones 15 pcf density	PT	4 × 40 mm	Tension loading	10	247 ± 137 N/mm	-	-	467 ± 214 N	2015 ± 540 N	2015 ± 540 N 535 ± 182 N 201 ± 123 N
				Adduction – axial loading	10	139 ± 67 N/mm	-	-	374 ± 156 N	535 ± 182 N	
				External rotation – transverse loading	10	45 ± 27 N/mm	-	-	109 ± 27 N	201 ± 123 N	
Wegner et al. [18]	Sawbones 4 th G	FT	2 (4.7 × 45 mm)	Tension loading	10	36 ± 15 N/mm	-	-	172 ± 142 N	317 ± 60 N	NA, sawbones blocks
				Shear	9	106.4 ± 15.8 N/mm	429.4 ± 11.7 N	7.2 ± 0.35 mm	-	565.9 ± 18.3 N	
				Axial displacement 0.5 mm/s	8	80.1 ± 27.5 N/mm	261.4 ± 26.1 N	4.3 ± 1.03 mm	-	533.0 ± 19.1 N	
Wegner et al. [18]	Sawbones 4 th G	PT	2 (4.0 × 40 mm)	Axial displacement 0.5 mm/s	10	360 ± 131 N/mm	-	-	719 ± 91 N	-	OTA 44–A2.3
				Axial loading 1 mm/s up to 6 mm and cycled back to 0 mm	10	180 ± 48 N/mm	-	-	342 ± 83 N	-	

FT: fully threaded (cortical), PT: partially threaded (cancellous).

4.4. Implications for practice

Our findings suggest that if decision is made to use screw constructs to treat FMM, the fully threaded screws and in particular the headless type, could be a better option than the partially threaded ones. With similar efficacy in terms of healing rate and time to heal, the significantly lesser complications with FT screws imply less post-operative pain, less screw loosening and consequently less revision rate for hardware removal.

4.5. Implications for research

This review could serve as a basis for more directed future research. For the main clinical outcomes, further large-sampled and controlled studies are needed to investigate the outcome differences in the healing rate between both methods. Types of fracture and screws should be taken into consideration for future research to enhance homogeneity between groups of comparison.

5. Conclusions

While acknowledging the limitations of this review, the results suggest that the use of fully threaded cortical screws is a better option than the partially threaded cancellous screws to treat fractures of the medial malleola. While displaying similar healing rate, the advantages of lesser complications were shown to reduce the rates of screw loosening and of hardware removal.

6. Brief summary

- Partially threaded cancellous screws are commonly used for internal fixation of medial malleolar fractures
- High rates of screw loosening and revision rates for implant removal have been reported following threaded screws
- Some authors reported similar union rates with fully threaded screws with less implant-related complications
- The clinical studies showed similar union rates between both methods but with significantly less complications and complication-related revision surgery following fully threaded screws
- The biomechanical studies on cadavers and sawbones demonstrated significantly better biomechanical properties with FT screws versus PT screws and that for all studied outcomes
- This systematic review concluded that fully threaded screws could yield better clinical and biomechanical outcomes compared to the partially threaded screw constructs for the treatment of medial malleolar fractures

Financial disclosure

We affirm that we have no financial affiliation or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript.

Statement of institutional review board

This study was approved by University’s Institutional Review Board.

Conflict of interest

The authors declared that they have no conflict of interest.

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