Surgical and Nonsurgical Management of Mallet Finger: A Systematic Review

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Purpose The current literature describes multiple surgical and nonsurgical techniques for the management of mallet finger injuries, and there is no consensus on the indications for surgical treatment. The objective of this study was to determine, through a literature review, if any conclusions can be drawn concerning the indications for surgery in mallet finger injuries; the treatment outcomes of surgical versus nonsurgical management; the most effective methods of surgical and nonsurgical treatment; and the most common treatment complications of mallet finger injuries.

Methods A systematic review of multiple databases was performed. English language clinical studies evaluating therapeutic interventions for mallet fingers that reported objective, standardized outcome measures were included. Basic science studies, cadaveric studies, conference abstracts, level V evidence studies, studies lacking statistical data, and tendinous injuries other than mallet fingers were excluded. Salvage procedures and studies evaluating exclusively chronic lesions were also excluded.

Results Forty-four studies that reported clinical outcomes for the treatment of mallet finger injuries, 22 evaluating surgical treatments and 17 studies investigating nonsurgical treatments were included. The average distal interphalangeal joint extensor lag was 5.7° after surgical treatment and 7.6° after nonsurgical treatment. Complication rates of surgical and nonsurgical interventions were comparable (14.5% and 12.8%, respectively). Five studies directly compared the outcomes of surgical with nonsurgical management, with mixed results and recommendations.

Conclusions Both surgical and nonsurgical treatments of mallet finger injuries lead to excellent clinical outcomes. Insufficient evidence is available to determine when surgical intervention is indicated. Based on our literature review, it appears that these treatments are equivalent and should be individualized to the patient. *(J Hand Surg Am. 2018;43(2):146–163. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Mallet finger, outcomes, splinting, surgery.

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Mallet finger injuries are common tendon injuries in the finger. The extensor tendon of the distal interphalangeal (DIP) joint may sustain damage of varying degrees, from partial tear to complete rupture, as characterized by Doyle's classification system[1] (Table 1, Fig. 1). The goal of management is to restore active DIP joint extension and prevent a swan neck deformity (DIP joint extensor lag and proximal interphalangeal joint hyperextension). Most mallet finger lesions can be

TABLE 1. Doyle Classification

Type	Characteristics
I	Closed injury ± avulsion fracture
II	Open injury (laceration at or around DIP joint)
III	Open injury + loss of skin and substance of the extensor tendon
IV	A: Growth plate fracture (pediatric) B: Fracture fragment involves 20% to 50% of articular surface (adult) C: Fracture fragment involves >50% of articular surface (adult)

treated nonsurgically by splinting, with the principal challenge being patient compliance.

There is no consensus regarding the indications for surgical intervention. Traditionally, surgeons recommended surgery for injuries involving more than one-third of the DIP joint articular surface[2,3] and those with subluxation or displacement.[4–6] Others have proposed nonsurgical management for almost all cases of mallet finger injuries, challenging the surgical indications.[7–10] To our knowledge, only 1 decision algorithm is described in the literature,[11] and it dictates the nonsurgical treatment of almost all mallet fingers, including injuries with fractures involving more than one-third of the articular surface with volar subluxation. Surgical treatment is advocated by these authors if the subluxation cannot be reduced by splinting.

The objective of this study was to determine through a literature review if any conclusions can be drawn concerning the indications for surgery in mallet finger injuries; the treatment outcomes of surgical versus nonsurgical management; the most effective methods of surgical and nonsurgical treatment; and the most common treatment complications of mallet finger injuries.

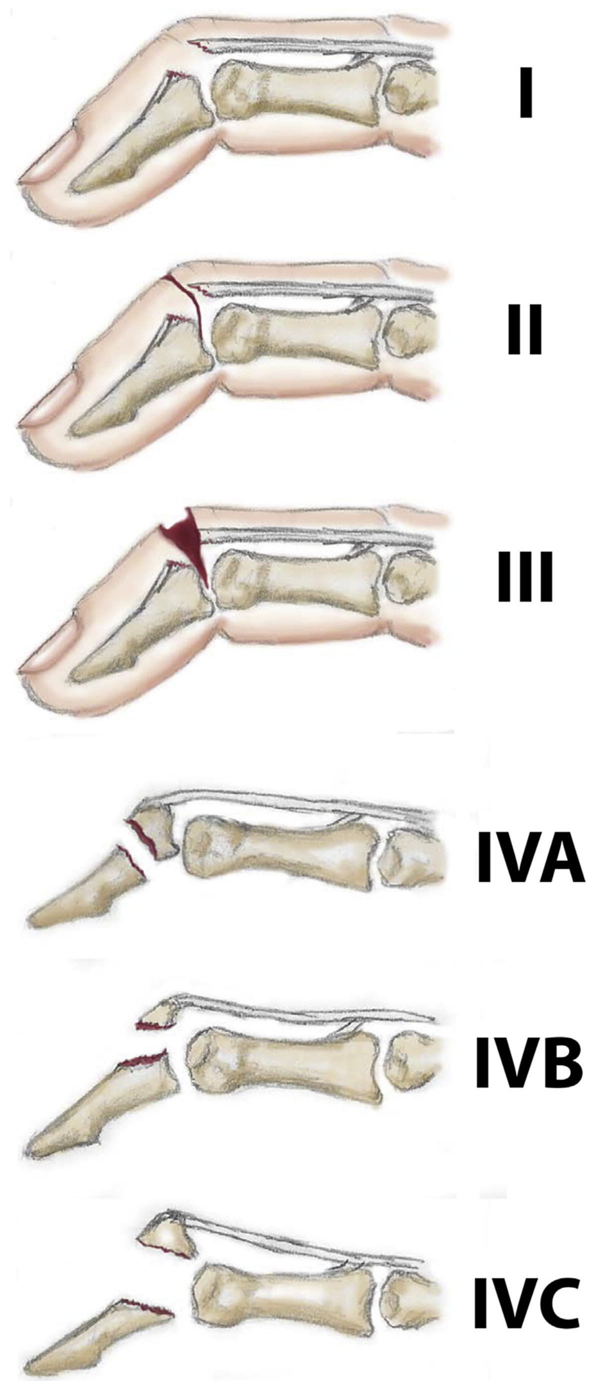

FIGURE 1: Doyle classification of mallet injuries.

MATERIALS AND METHODS

We conducted a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[12] guidelines (Fig. 2). The search strategy was based on "mallet finger," and the authors independently confirmed the search on March 5, 2017. The following databases were used: PubMed, Scopus, CINAHL, The Cochrane Library, and clinicaltrials.gov. Results from web search engines and references of included articles were reviewed for potentially relevant studies missed by the initial search. All abstracts were manually screened, and the full text of all studies with potential for final inclusion was evaluated for eligibility by the first author.

Inclusion criteria required English language clinical studies evaluating any therapeutic intervention of mallet finger injury that reported an objective, standardized outcome measure with evidence level IV or higher. Basic science studies, cadaveric studies, conference abstracts, and studies not reporting

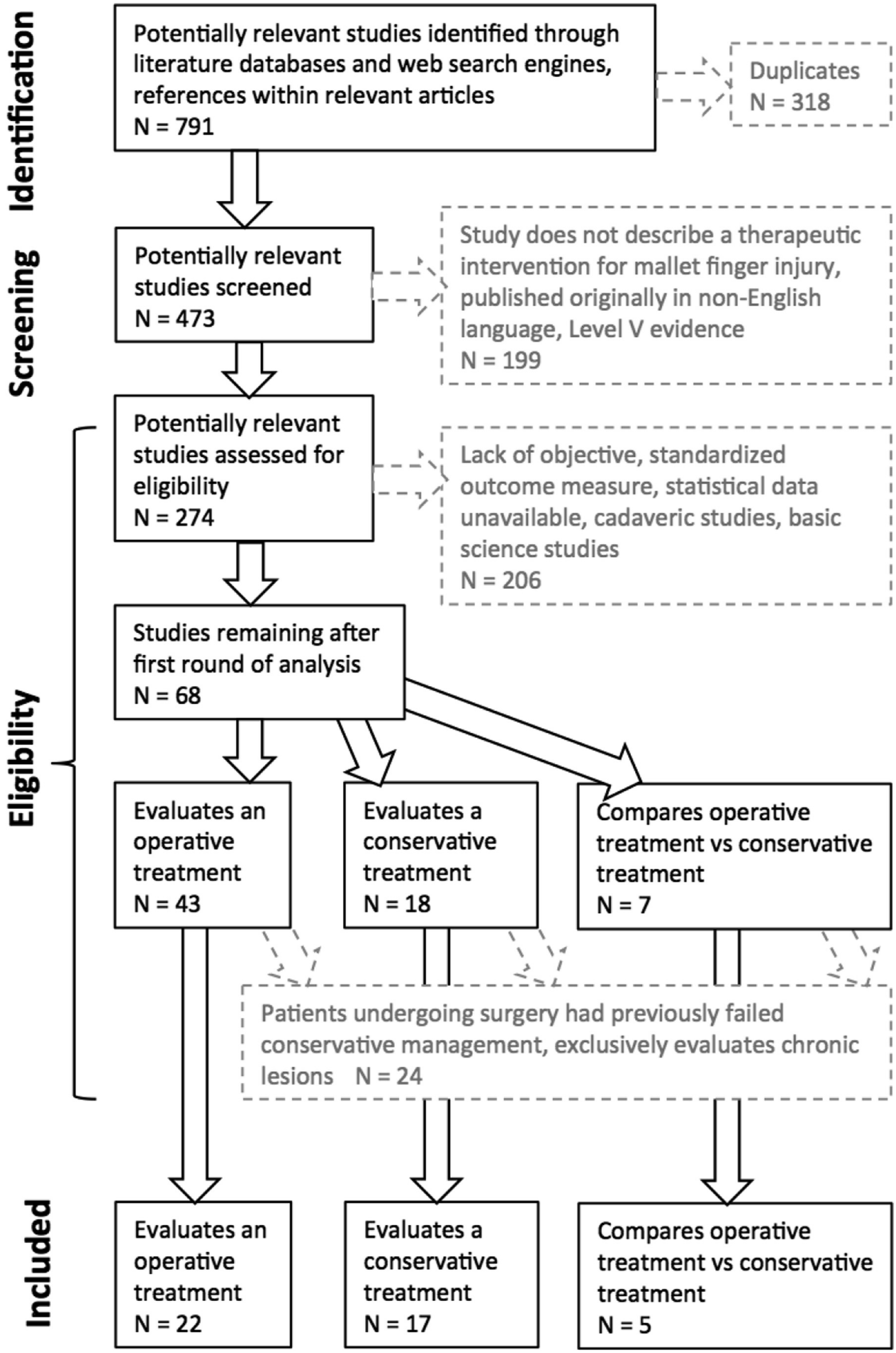

FIGURE 2: Search strategy according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Forty-four studies were identified for inclusion, which are separated into 3 categories.

TABLE 2. Quality Appraisal Tool[13]

Item	Description
1	Thorough literature review to define the research question
2	Specific inclusion/exclusion criteria
3	Specific hypotheses
4	Appropriate scope of psychometric properties
5	Sample size calculation/justification
6	Appropriate retention/follow-up
7	Authors referenced specific procedures for administration, scoring, and interpretations of procedures
8	Measurement techniques were standardized
9	Data were presented for each hypothesis
10	Appropriate statistics-point estimate
11	Appropriate statistical error estimates
12	Valid conclusions and clinical recommendation

Each item was assigned a score of 0, 1, or 2. Studies received a score of 0 if an item was omitted or not performed. A score of 1 was assigned for partial completion of an item. The maximum score of 2 was assigned for total fulfillment of the item.

clinical data were excluded. To eliminate the variability between salvage procedures and primary mallet injury treatments, we excluded studies that evaluated operations for mallet fingers that had previously failed nonsurgical treatment, as well as studies that exclusively investigated chronic lesions.

The quality of all included studies was independently evaluated by both authors using the Quality Appraisal Tool (QAT) (Table 2; and Appendices A-C, available on the *Journal's* Web site at www.jhandsurg.org).[14] Originally described by MacDermid et al,[13] this 12-item appraisal tool assesses the methodological characteristics of each study. Each item receives a score of 0, 1, or 2, indicating omission, partial fulfillment, and complete fulfillment of the item, respectively. Higher quality studies receive higher scores and therefore a higher percentage rating. If there was any disagreement in scoring, the authors reached agreement through discussion.

Continuous variable data were reported as mean and standard deviations from the mean. Categorical variable data were reported as frequency with percentages. Associations were reported as odds ratio with the corresponding 95% confidence interval. Statistical significance was set at $P < .05$.

RESULTS

Forty-four studies were identified for final inclusion and analysis, with 22 evaluating surgical treatments, 17 evaluating nonsurgical treatments, and 5 studies comparing surgical with nonsurgical treatments. The Mean QAT rating of all studies was 73.4% ± 16.9% (range, 33.3% to 100%).

Surgical treatment of mallet finger

A total of 511 mallet fingers underwent surgery (Table 3). Four hundred and eighty cases were bony (associated fracture) injuries (93.9%), and 31 were tendinous (soft tissue only) injuries (6.1%). Of the 22 studies, 20 evaluated exclusively bony injuries. Two studied only soft tissue injuries. Thirteen studies used the Crawford criteria[35] to grade their outcomes (Table 4), and all other studies reported the mean DIP joint extension lag as an objective outcome measure. Several studies included standardized evaluation criteria such as the 3-tiered classification, described by Abouna and Brown[36] (Table 5) and Warren and Norris.[37] The average DIP joint extension deficit was 5.7°. There was no clinically notable difference in primary outcomes between bony and tendinous injuries in these studies. The mean postoperative DIP joint extensor deficit of the 480 bony injuries was 5.5° versus 7.5° for the 31 soft tissue injuries.

The most commonly described surgical techniques included trans-DIP joint K-wire fixation, open reduction internal fixation with K-wire, and open suture repair of the tendon plus trans-DIP joint K-wire fixation (tenodermodesis). Acar et al[30] were the only authors to directly compare 2 different surgical techniques, and it was the only surgical study that was evidence level III, with all other articles therapeutic level IV.

Indications for surgical treatment

The most frequently described surgical indications were size of fracture (more than one-third of articular

TABLE 3. Clinical Studies Evaluating Surgical Treatment of Mallet Finger

Authors	No. of Cases	Bony vs Soft	Intervention	Indications for Operation	Results			
					Crawford Criteria EGFP (%)*	DIP Joint Extension Deficit (°)	Other Evaluation Criteria Used†	Complications
Hamas et al[2] (1978)	11	Bony	ORIF K-wire + trans-DIP K-wire	Fractures >1/3 articular surface	—	2	—	0
Inoue[15] (1992)	14	Bony	Closed reduction using extension-block K-wire (Ishiguro)	Fractures >1/3 articular surface ± subluxated distal phalanx	E57, G29, F7, P7		—	0
Bischoff et al[16] (1994)	51	Bony	Tension band fixation wiring	Fractures >25% articular surface and rotated, distal phalanx subluxation	—	15	20% excellent, 39% satisfactory, 41% poor	24 total complications: 4 skin breakdown, 6 infection, 3 secondary displacement, 6 nail growth disruption, 1 AVN, 1 secondary tendon rupture, 4 resorption of fragment
Nakamura and Nanjyo[17] (1994)	15	Soft	Sutures + trans-DIP K-wire, early mobilization	Patients who required fine manual dexterity	—	6	67% excellent or good, 20% fair, 13% poor	0
Darder-Prats et al[18] (1998)	22	Bony	Closed reduction using extension-block K-wire (Ishiguro)	Fractures >1/3 articular surface	E82, G14, F5		-	1 skin necrosis, 1 tendon rupture
Bauze and Bain[19] (1999)	10	Bony	Sutures + trans-DIP K-wire	Fractures >30% articular surface	—	11	VAS and plain radiographs	2 nail deformities, 1 superficial infection, 1 pin track infection
Takami et al[6] (2000)	33	Bony	ORIF with K-wires	Fractures >1/3 articular surface with rotation, joint subluxation	—	4	Cosmetic: 73% excellent, 27% good	1 fragmentation of a bone fragment and displacement of bone
Hofmeister et al[20] (2003)	24	Bony	Closed reduction using extension-block K-wire (Ishiguro)	Fractures >25% articular surface or DIP subluxation	E38, G54, F8	4	Warren and Norris 92% success, 4% improved, 4% failure	2 superficial pin-site infections, 2 slight displacement of reduction

(Continued)

TABLE 3. Clinical Studies Evaluating Surgical Treatment of Mallet Finger (Continued)

Authors	No. of Cases	Bony vs Soft	Intervention	Indications for Operation	Results: Crawford Criteria EGFP (%)*	Results: DIP Joint Extension Deficit (°)	Results: Other Evaluation Criteria Used†	Complications
Pegoli et al[21] (2003)	65	Bony	Closed reduction using extension-block K-wire (Ishiguro)	Large bone fragment, palmar subluxation of loss of DIP joint congruity or extension lag >30°	E46, G32, F20, P2		–	1 pin tract infection, 2 nail deformities
Sorene and Goodwin[22] (2004)	16	Soft	Tenodermodesis (sutures + trans-DIP K-wire)	Fractures >1/3 articular surface should undergo ORIF, functionally important loss of extension in established lesions, cosmetic Passively correctable deformity with a good articular surface should undergo tenodermodesis	–	9	50% excellent, 37.5% good, 12.5% fair	0
Teoh and Lee[23] (2007)	9	Bony	ORIF with the “hook” plate technique	Fractures >1/3 articular surface, volar subluxation of distal phalanx	E44, G56	0	Warren and Norris 100% success	0
Lee et al[24] (2009)	32	Bony	Two extension block K-wire technique	Fractures >1/3 articular surface ± subluxated distal phalanx	E69, G25, F6		–	3 nail ridging, 2 superficial infection, 2 transient nail deformity, 1 mild scarring at dorsal pin
Lee et al[25] (2010)	29	Bony	Two extension block K-wires + trans-DIP K-wire	Fractures >30% articular surface ± subluxated distal phalanx	E73, G21, F6	4	–	0
Kang and Lee[26] (2012)	16	Bony	Open reduction, oblique wire fixation w/ pulp traction + primary extensor repair	Fractures >30% articular surface + subluxated distal phalanx, displacement >3 mm irreducible extension block pinning	E69, G19, F12.5		–	3 transient nail deformity, 2 cases flexion lag 5° to 10°, 3 cases extension lag 5° to 10°

(Continued)

TABLE 3. Clinical Studies Evaluating Surgical Treatment of Mallet Finger (Continued)

Authors	No. of Cases	Bony vs Soft	Intervention	Indications for Operation	Results			
					Crawford Criteria EGFP (%)*	DIP Joint Extension Deficit (°)	Other Evaluation Criteria Used†	Complications
Kakinoki et al[27] (2013)	13	Bony	Tension band wiring fixation	Applicable for mallet fractures of all sizes and time after injury	–	0	77% very satisfied, 23% satisfied	1 osteophyte formation, 1 DIP joint motion restriction
Miura[28] (2013)	12	Bony	External fixator + K-wire	Fractures >1/3 articular surface	E10, G2	2	–	0
Neuhaus et al[29] (2013)	3	Bony	Closed reduction and internal fixation w/ K-wires	Closed bony mallet finger with subluxation	–	0	–	0
Acar et al[30] (2015)	32	Bony	Hook plate fixation (n = 13) vs Extension block pinning (Ishiguro) (n = 19)	Fractures >1/3 articular surface, volar subluxation of distal phalanx	E62, G38 vs E53, G47	3 vs 4	DASH: 0.5 vs 1.8 VAS: 0.0 vs 0.6	Hook plate: 3 nail deformity Extension block pinning: 1 nail deformity, 2 dorsal prominence, 1 degenerative joint
Miranda et al[31] (2015)	12	Bony	Percutaneous blunt needle reduction	Fractures >1/3 articular surface, minimal bony contact postreduction, volar subluxation of distal phalanx	–	5	–	1 dorsal bump with mild fragment displacement
Imoto et al[32] (2016)	25	Bony	ORIF hook plate and screw	Fractures >1/3 articular surface, volar subluxation of distal phalanx	E40, G60		–	0
Kim et al[33] (2016)	26	Bony	K-wire catches dorsal fragment (fish hook) + trans-DIP K-wire	Fractures >1/3 articular surface, volar subluxation of distal phalanx	E77, G19, F4	3	–	0
Zhang et al[34] (2016)	41	Bony	K-wire pressing fixation of fragment + trans-DIP K-wire	Fractures >1/4 articular surface	E85, G10, F2, P2	4	–	6 nail deformity, 3 arthritis, 1 mild swan-neck deformity

When 2 or more sets of results are reported with "vs," the scores belong to each intervention method respectively in the order described.

AVN, Avascular necrosis; DASH, Disabilities of the Arm, Shoulder and Hand; DIP, distal interphalangeal; EGFP, E (excellent), G (good), F (fair), P (poor); ORIF, open reduction internal fixation; VAS, visual analog scale.

*Percentages may not sum to 100 because of rounding.

†Specific criteria for outcome categories were unique to the study unless otherwise specified.

TABLE 4. Crawford Criteria (1984) Assessment of Mallet Finger Outcomes

Grade	Characteristics of DIP Joint
Excellent	Full extension Full flexion No pain
Good	Extension deficit 0° to 10° Full flexion No pain
Fair	Extension deficit 10° to 25° Any flexion loss No pain
Poor	Extension deficit >25° Persistent pain

DIP, distal interphalangeal.

TABLE 5. Abouna and Brown Criteria (1968)

Grade	Characteristics of DIP Joint
Success	Extension deficit <5° Normal flexion No stiffness
Improved	Extension deficit 6° to 15° Normal flexion No stiffness
Failure	Extension deficit >15° Any flexion loss DIP stiffness

DIP, distal interphalangeal.

surface involvement) (82.6%) and subluxation of the distal phalanx (60.9%). Cosmetic reasons and patients requiring fine manual dexterity were also cited as surgical indications, each appearing once in these studies (4.5%).

Complications of surgical treatment

A total of 74 complications (rate 14.5%) were reported (Table 3), with the most common being nail deformity (5.5%) and infection (2.5%). Other reported complications included secondary displacement of the reduction (1.4%), skin breakdown (1.2%), arthritis (0.8%), resorption of the bone fragment (0.8%), tendon rupture (0.4%), 1 instance of avascular necrosis of the fragment (0.2%), and 1 swan neck deformity (0.2%).

Nonsurgical treatment of mallet finger

A total of 1,098 mallet fingers in 17 studies were managed nonsurgically (Table 6). Seven hundred and twenty cases were soft tissue-only injuries. Two hundred and ninety-six cases had bony involvement. The type of injury was unspecified for 82 cases in the studies by Evans and Weightman[39] and Tocco et al;[49] the former study did not comment on injury type, whereas the latter mentioned soft tissue and bony injuries but did not specify how many of each they treated. The majority of studies, 12 of 17 (70.6%), included both bony and soft tissue mallet finger injuries and did not separate them in their outcomes analyses. Three studies investigated only soft tissue injuries, and 1 study investigated only bony mallet finger injuries with fracture fragments greater than one-third of the articular surface.

All but one of these studies evaluated some form of splinting. Hovgaard and Klareskov[40] evaluated an elastic double-finger bandage for the treatment of mallet finger. The outcomes were overall favorable with nonsurgical treatment options. The majority of nonsurgical treatment studies reported DIP joint extension deficit as an outcome measure. Many also employed Abouna and Brown and Crawford criteria to grade outcomes. The average DIP joint extension deficit was 7.6°.

Of the 17 studies, 9 were evidence level IV,[9,35,39–41,43–46] 1 study was evidence level III (retrospective cohort),[50] 3 studies were evidence level II (randomized controlled trials with <80% follow-up),[38,47,48] and 4 studies were evidence level Ib (randomized controlled trials).[37,42,49,51] The most commonly evaluated nonsurgical treatment for mallet finger included Stack splints, custom thermoplastic splints, and foam-padded aluminum splints. The mean length of continuous immobilization among all the studies was 7.0 ± 1.2 weeks. No studies reported differences in outcomes between tendinous-only versus bony injuries.

Seven studies directly compared the outcomes of 2 or more different types of splints. Most of these studies did not find statistically different outcomes in DIP joint extension deficit. Kinninmonth and Holburn[38] compared a perforated thermoplastic splint to a conventional Stack splint, contending that the perforated splint gave superior results, although no statistical analysis was performed. Warren et al[37] compared Stack and Abouna splints, and although both splints were deemed effective, the Stack splint was preferred by patients because of comfort. Maitra and Dorani's study[42] found equal effectiveness between a custom-made padded aluminum splint and the Stack splint, but the aluminum splint caused fewer skin complications. Pike et al[47] compared a volar aluminum splint, dorsal aluminum splint, and a

TABLE 6. Clinical Studies Evaluating Conservative Treatment of Mallet Finger

Authors	No. of Cases	Bony vs Soft	Intervention (Length of Immobilization)	Treatment Indications	Recommendation	Results: Crawford Criteria EGFP (%)*	Results: DIP Joint Extension Deficit (°)	Results: Other Evaluation Criteria Used†	Results: Complications
Crawford[35] (1984)	151	62 soft 89 bony	Stack splint (molded polythene splint) (8 wk)	Tendon rupture or laceration	Open reduction should only be reserved for distal phalanx subluxations	E64, G15, F11, P8		-	1 contact dermatitis
Kinninmonth and Holburn[38] (1986)	54	42 soft 12 bony	Perforated thermopliable splint (n = 27) vs Stack splint (n = 27) (6–12 wk)	All mallet fingers in their ED	Perforated splint is superior to conventional splint, does not require removal for hygiene purposes	—	—	89% vs 67% good/excellent for perforated vs conventional splints	1 irritation secondary to exposure to hand disinfectant
Evans and Weightman[39] (1988)	25	Unknown	Piplex splint, DIP joint extension, PIP joint flexion (5.8 wk; range 3–11 wk)	Rupture or avulsion of extensor insertion	Preventing full PIP extension shortens treatment time	—	60% <10 28% 10–20 12% >20	—	0
Hovgaard and Klareskov[40] (1988)	25	21 soft 4 bony	Elastic double-finger bandage, allowing some degree of flexion (6–8 wk)	Closed injuries	This hygienic and simple bandage is equally effective as splinting	—	3	68% good 28% fair 4% poor	0
Warren et al[37] (1988)	107	74 soft 33 bony	Stack splint (n = 58) vs Abouna splint (n = 49) (6 wk continuous + 2 wk night only)	Exclude large bony fragment, fresh open injuries, epiphyseal injuries in children	Both splints are effective in many types of mallet finger. There is no category of injury not worth treating. Stack splint is preferred by the patient because of comfort	—	—	Abouna and Brown: 33% vs 39% success 19% vs 14% improved 48% vs 47% failure	Abouna splint: 3 skin lacerations due to bare wire being exposed

(Continued)

TABLE 6. Clinical Studies Evaluating Conservative Treatment of Mallet Finger (Continued)

Authors	No. of Cases	Bony vs Soft	Intervention (Length of Immobilization)	Treatment Indications	Recommendation	Results: Crawford Criteria EGFP (%)*	Results: DIP Joint Extension Deficit (°)	Results: Other Evaluation Criteria Used†	Results: Complications
Shankar and Goring[41] (1992)	100	42 soft 58 bony	Stack splint (molded polythene splint) (6–9 wk)	Closed injury w/ fracture <1/3 joint surface	Mallet fingers without substantial fracture can be treated with Stack splint	—	12	—	18 fingers became obstructive, 50 cold intolerance, 5 constant pain
Maitra and Dorani[42] (1993)	60	50 soft 10 bony	Custom-made padded aluminum alloy splint (n = 30) vs Stack splint (n = 30) (6 wk continuous + 3 wk night only)	Closed injury w/o large fracture fragment	Custom-made padded aluminum splint equally effective as Stack splint but caused fewer skin complications	—	—	Abouna and Brown: 37% vs 33% success 20% vs 20% improved 43% vs 47% failure	Custom aluminum splint: 1 dorsal ulcer, 1 skin maceration Stack splint: 3 dorsal ulcer, 6 skin maceration, 1 tape allergy
Garberman et al[43] (1994)	40	27 soft 13 bony	Stack splint or aluminum foam splint (no difference in outcome) (7 wk; range 6–10 wk continuous + 4 wk night only)	Closed injury w/ fracture <1/3 joint surface, no DIP joint subluxation	Recommend splinting for closed mallet fingers w/ fracture <1/3 articular surface and no subluxation No difference in timing of presentation (4 d vs 8 wk)	—	9	Abouna and Brown (modified): 80% success 20% failure	0
Foucher et al[44] (1996)	156	146 soft 10 bony	Perforated thermoplastic splint (8 wk)	Closed injury w/ fracture <1/3 joint surface	Perforated splint provided excellent results for closed mallet finger w/ fractures <1/3 articular surface	—	7	—	0
Lester et al[45] (2000)	37	27 soft 10 bony	Foam-padded aluminum splint (4–5 wk)	Closed injury	Recommend splinting of DIP joint in 0° extension as opposed to hyperextension	E81, G14, F/P5		Warren and Norris 95% success 5% failure	0

(Continued)

TABLE 6. Clinical Studies Evaluating Conservative Treatment of Mallet Finger (Continued)

						Results			
Authors	No. of Cases	Bony vs Soft	Intervention (Length of Immobilization)	Treatment Indications	Recommendation	Crawford Criteria EGFP (%)*	DIP Joint Extension Deficit (°)	Other Evaluation Criteria Used†	Complications
Richards et al[46] (2004)	34	26 soft 8 bony	Custom-made thermoplastic splint (6 wk)	Closed injury w/ fracture <1/3 joint surface	Custom-made splint may be preferable to a standard splint	—	—	Abouna and Brown: 88% success 12% failure	0
Kalainov et al[9] (2005)	22	Bony	Thermoplastic extension splint (5.5 wk + 3 wk night only)	Closed and displaced fractures w/ >1/3 joint surface	Supports splinting for closed and displaced mallet fractures >1/3 surface	—	9	VAS, ADL tolerance	2 transient skin infection
Pike et al[47] (2010)	77	Soft	Volar aluminum (n = 27) vs dorsal aluminum (n = 26) vs custom thermoplastic splints (n = 24) (6 wk)	Acute (<28d) Doyle 1 injury (closed injury ± fracture <1/3 joint surface)	No statistically significant lag difference between these 3 splints	—	6	MHQ	Dorsal padded aluminum splint: 1 full-thickness ulceration 6 minor complications (2 in each group): irritation and altered sensation
O'Brien and Bailey[48] (2011)	64	37 (14, 12, 11) soft 27 (7, 9, 11) bony	Stack (n = 21) vs dorsal aluminum (n = 21) vs custom thermoplastic splints (n = 22) (8 wk)	Acute (<14d) Doyle 1 injury (closed injury ± fracture <1/3 joint surface)	Custom thermoplastic splint less likely to result in treatment failure, but no extensor lag difference	E65, G18, F16, P2	3	VAS	Stack splint: 19 complications Dorsal aluminum: 8 complications Thermoplastic: 5 complications (12 Skin irritation/ maceration, 9 poor splint fit, 4 splint dissatisfaction, 4 splint breakage, 3 pain)

(Continued)

TABLE 6. Clinical Studies Evaluating Conservative Treatment of Mallet Finger (Continued)

Authors	No. of Cases	Bony vs Soft	Intervention (Length of Immobilization)	Treatment Indications	Recommendation	Results: Crawford Criteria EGFP (%)*	Results: DIP Joint Extension Deficit (°)	Results: Other Evaluation Criteria Used†	Complications
Tocco et al[49] (2013)	57	Soft and small bony (<1/3) Not separated	Quickcast splint (n = 27) vs lever-type thermoplastic splint (n = 30) (6−8 wk)	Closed injury, ≥20° DIP joint lag passively correctable, fracture <1/3 joint surface	Cast immobilization more effective than the traditional approach—less edema and improved extensor lag	−	5 vs 9	Garberman success scale	Cast: 4 trace maceration at latest follow-up Thermoplastic splint: 4 trace maceration at latest follow-up
Altan et al[50] (2014)	45	Soft	Extension splinting− early vs delayed treatment (no difference in outcome) (6 wk)	Closed tendinous injury (Doyle 1a)	Conservative management of tendinous mallet finger is effective even if delayed presentation (up to 4 wk)	E72 vs E59‡	7	−	1 skin maceration
Saito and Kihara[51] (2016)	44	Soft	Two-step splint technique (n = 22) vs conventional splint (n = 22) (6 wk continuous + 2−4 wk night only)	Acute (<14d) closed injury ± fracture, no subluxation	Initial immobilization in 2-step splint is a good immobilization technique. Prefer 2-step splint over conventional	−	7.5 vs 16	Abouna and Brown: 60% vs 10% success 35% vs 40% improved 5% vs 50% failure	0

When 2 or more sets of results are reported with "vs," the scores belong to each intervention method respectively in the order described.
ADL, activities of daily living; DIP, distal interphalangeal; EGFP, E (excellent), G (good), F (fair), P (poor); PIP, proximal interphalangeal; VAS, visual analog scale.
*Percentages may not sum to 100 because of rounding.
†Specific criteria for outcome categories were unique to the study unless otherwise specified.
‡Good, fair, and poor results not reported, difference not statistically significant.

TABLE 7. Clinical Studies Comparing Outcomes of Conservative Treatment Versus Surgical Treatment

					Results			
Authors	No. off Cases	Bony vs Soft	Conservative Intervention	Surgical Treatment	Recommendation	DIP Joint Extension Deficit (°)	Other Evaluation Criteria Used	Complications
Auchincloss[52] (1982)	22 19	Unknown	Pryor and Howard splint	Trans-DIP K-wire	Comparable results. Internal K-wire fixation may be better if delayed presentation	10 vs 6	Stark, Boyes, and Wilson 50% vs 58% good 32% vs 37% improved 18% vs 5% unchanged	Splint: 3 severe local irritation Surgery: 2 infection
Wehbe and Schneider[7] (1984)	15 6	Bony	Palmar, dorsal aluminum-foam or Stack splint, cast	Pull-out wire suture + K-wire internal fixation + trans-DIP K-wire	Most mallet fractures can be treated conservatively, regardless of joint subluxation and size/amount of fragment displacement	15 (combined)	—	Splint: 1 superficial maceration, 2 erythema of DIP joint Surgery: 1 lost reduction, 1 pull-out button detachment, 1 lost splint and had arthrodesis that remained painful
Groebli et al[53] (1987)	4 17	Bony	Pryor polythene splint	Open reduction, trans-DIP K-wire + pull-out w/ hook	Abandon conservative treatment early if no reduction. Surgery must be performed soon after injury. Splint is preferable if delayed presentation (>15 d)	—	50% vs 53% excellent (DIP joint any deficit <10°) 50% vs 28% moderate (DIP joint any deficit >10°) 0% vs 18% failure (stiffness or arthrodesis)	Splint: 0 Surgery: 3 dystrophic pulp w/ hypoesthesia, 3 cold sensitivity
Lubahn[54] (1989)	11 19	Bony	Link-type or dorsal aluminum-foam splint	Trans-DIP K-wire + ORIF with K-wire	Open treatment preferable for fractures >1/3 articular surface and joint subluxation	20–30 vs 0–20	35° vs 55° average ROM	Splint: 1 dorsal skin slough Surgery: 1 pin tract infection

(Continued)

TABLE 7. Clinical Studies Comparing Outcomes of Conservative Treatment Versus Surgical Treatment (Continued)

Authors	No. off Cases	Bony vs Soft	Conservative Intervention	Surgical Treatment	Results			
					Recommendation	DIP Joint Extension Deficit (°)	Other Evaluation Criteria Used	Complications
Renfree et al[55] (2016)	44 17	10 bony, 34 soft vs 8 bony, 9 soft	Custom thermoplastic splint	Trans-DIP K-wire	Recommend extension splint for most closed soft or bony mallet injuries. K-wire fixation requires less stringent compliance, advantageous depending on occupation	10 vs 5	—	Splint: 1 swan neck deformity, 1 decubitus ulcer Surgery: 1 cellulitis, 1 pin migration, 1 swan neck deformity removed from final data analysis as the patient received both splint and pinning

When 2 or more sets of results are reported with "vs," the scores belong to each intervention method respectively in the order described.
DIP, distal interphalangeal; ORIF, open reduction internal fixation; ROM, range of motion.

custom thermoplastic splint, and found no statistically significant difference in extensor deficit. O'Brien and Bailey[48] compared Stack splints, dorsal aluminum splints, and custom thermoplastic splints, and found no difference in extensor lag. Tocco et al[49] compared a Quickcast splint to a thermoplastic splint, and found that casting led to less edema and improved extensor lag, although there were no statistically significant differences. Saito and Kihara[51] compared a 2-step splint technique to a conventional figure-eight splint; the 2-step technique resulted in significantly better outcomes based on extension deficit and the Abouna-Brown criteria.

Indications for nonsurgical treatment

The most commonly reported indications for nonsurgical treatment were closed injury (82.4%) and a fracture fragment size <1/3 of the joint surface area (58.8%). Four studies (23.5%) explicitly required the absence of subluxation.[43,47,48,51] Three studies (17.6%) required presentation to be acute (either within 14 or 28 d from injury).[47,48,51] One study specifically studied fractures with sizes >1/3 of the joint surface area.[9]

Complications of nonsurgical treatment

A total of 140 complications were reported (rate, 12.8%), almost all of which were mild and transient, including cold intolerance (4.6%) and mild skin issues (4.2%), such as skin irritation, transient infection, allergy, maceration, laceration, and ulcers. Only 1 case of serious full-thickness skin ulceration was reported, which occurred with a dorsal-padded aluminum splint and which required antibiotics.[47] Other reported complications included splint breakage, splint dissatisfaction, and persistent pain.

Comparison between nonsurgical and surgical treatment of mallet finger

A total of 174 cases were evaluated in 5 studies that directly compared nonsurgical (N = 96) with surgical (N = 78) treatment (Table 7). At least 90 cases (51.7%) involved a bony injury and 43 cases were solely tendinous (24.7%). One study did not specify how many of each injury type were included.[52] Three studies exclusively investigated bony injuries.[7,53,54] One study included both soft and bony injuries in its 2 treatment arms, reporting no difference in outcome between the injury types.[55] All studies compared splinting with trans-DIP joint K-wire treatment. One was level Ib (randomized controlled trial),[52] and the other 4 studies were evidence level III (retrospective cohort studies).[7,53–55] The recommendations and outcomes were varied.

Two studies found comparable clinical results between splinting and surgery. Auchincloss[52] and Renfree et al[55] did find improved DIP joint extension deficit with surgical treatment compared with splinting, but both suggested the treatments were comparable from a clinical standpoint. Auchincloss[52] suggested that internal K-wire fixation might achieve better results with delayed presentation.

In contrast, a study by Groebli et al[53] reported that splinting is preferred over surgery in cases of delayed presentation (>15 d). However, these authors recommended surgery if incongruity of the joint surface persisted and for all open injuries. Lubahn[54] contends that surgery is preferable in cases with joint subluxation and fractures involving more than one-third of the articular surface, because he found improved DIP joint extensor lag and cosmetic appearance in those cases. In contrast, Wehbe and Schneider[7] recommend nonsurgical treatment for most mallet fingers regardless of joint subluxation or size of fracture.

DISCUSSION

Indications for surgery in mallet finger injuries

A 2008 Cochrane review by Handoll and Vaghela[56] analyzing 4 randomized clinical trials determined that there was insufficient evidence to recommend specific surgical indications. The majority of the surgical studies in this systematic review recommended using the size of the fracture fragment (82.6%) and subluxation of the distal phalanx (60.9%) as operative indications. Of note, failure of nonsurgical treatment was also one of the most commonly reported surgical indications encountered in the overall literature; over a third (35%) of the initial 43 surgical articles cite "failure of conservative treatment" as an indication for operation (Fig. 2). However, we excluded articles that studied operations for injuries that previously failed nonsurgical treatment as well as articles that studied exclusively chronic injuries (>28 d at presentation). We felt it would be inappropriate to compare salvage procedures with the primary treatment of mallet finger. On that basis, 22 surgical studies remained in our final analysis.

Although not explicitly stated in the surgical articles, open injuries are likely indications for surgical management as well. We infer this based on the fact that 14 of 17 articles (82.4%) describing nonsurgical treatments required that the injury be closed in the patients they evaluated. In addition, the 3 articles that did not specify this requirement are the 3 oldest nonsurgical articles,[35,38,39] none of which received a full QAT score for detailing specific inclusion/exclusion criteria or demographic information (Appendix B). Therefore, it is possible that all patients treated nonsurgically in these studies sustained only closed injuries. Alternatively, almost none of the surgical studies specify how many of their injuries were open or closed. As a result, we were unable to directly compare outcomes of open versus closed mallet finger injuries under the various treatment methods.

Treatment outcomes of surgical versus nonsurgical management

Lubahn[54] compared splinting with surgery, and recommended surgical management for patients who desire better outcomes for functional or cosmetic reasons. Renfree et al[55] also compared splinting with K-wire fixation and contended that surgery is justified in patients who might have difficulty working with a splint, such as health care professionals or musicians. Overall, surgery may offer a slightly decreased, but likely clinically insignificant, mean DIP joint extension deficit compared with nonsurgical management, based on the interstudy calculations of 5.7° and 7.6°, respectively. This small advantage would be consistent with the 3 studies that directly compared splinting and surgery[52,54,55] and which found improved DIP extensor lag in surgical cases compared with cases treated with splinting. However, these authors still recommended nonsurgical treatment for most cases of mallet injury, as a slight quantitative advantage in extensor lag with surgery may not be clinically significant.

There are those who recommend nonsurgical management for almost all mallet finger injuries, even in cases with large fracture fragments and distal phalanx subluxation.[7–10] Wehbe and Schneider[7] directly compared splinting with surgery, and they found that surgical treatment offered no advantage while increasing morbidity. Kalainov et al[9] evaluated the use of a thermoplastic splint in closed and displaced mallet finger fractures involving greater than one-third of the articular surface, finding good results and no difference in outcomes between those with DIP joint subluxation and those without.

Most effective methods of surgical and nonsurgical treatment

The optimal treatment for mallet finger injuries remains controversial. The large majority of surgical techniques involved some use of trans-DIP joint K-wire fixation. All but one nonsurgical management technique involved some form of splinting. Both surgical and nonsurgical techniques described in these studies generally yielded favorable outcomes with high proportions of cases receiving an "excellent"/"good" grade according to the Crawford criteria.

There is also no consensus on how to best evaluate patient outcomes. Most of the included studies reported DIP joint extension deficit, but the clinical significance of this measure is debatable, as some authors contend that there is no correlation between extension lag and patient satisfaction.[7,57,58] The Crawford criteria was the most commonly employed classification system. It is a 4-tiered grading system based on extension/flexion loss of the DIP joint and pain (Table 3) with high clinical relevance.[11] The 3-tiered grading system described by Abouna and Brown[36] (Table 5) based on DIP joint extension/flexion and stiffness was also commonly used. The Michigan Hand Outcomes Questionnaire,[59] visual analog scale, and Disabilities of the Arm, Shoulder, and Hand[60] were also employed to measure patient satisfaction and tolerance of activities of daily living.

Treatment complications of mallet finger injuries

This systematic review demonstrated complication rates of 12.8% (nonsurgical) and 14.5% (surgical). The most common complications of surgical treatment were nail deformities and infection. Surgery was more likely to result in serious complications such as secondary displacement of the reduction, tendon rupture, and skin necrosis. In contrast, there was only 1 serious complication reported with nonsurgical treatment, where a full-thickness skin ulceration occurred with a dorsal-padded aluminum splint. The most common complications of nonsurgical treatment were mild and transient skin issues such as irritation, laceration, and maceration. Although cold intolerance was the complication with the highest number of reported cases, all 50 cases were described in a single study,[41] making it less likely to be the most common complication of nonsurgical treatment in general.

Overall, our nonsurgical and surgical complication rates of 12.8% and 14.5%, respectively, are lower than some previously reported rates. A study by Stern and Kastrup[61] suggests that the complication rate of splinting is as high as 45%, and of surgery as high as 53%. King et al[62] reported surgical complication rates of 41%. Other studies have suggested that complications occur less frequently with surgery compared with nonsurgical treatments, which differs from our findings.[11] Our findings are similar to previously published reports that complications of surgical intervention are more severe than those of nonsurgical treatment, with nail deformity and infection being the most common. Overall, the treatments analyzed appeared to be very effective in preventing swan neck deformities, with a total of 2 mild occurrences isolated to 2 studies. One occurred in a patient having received an operation involving trans-DIP joint K-wire fixation (Zhang et al[34]). The other was observed in a patient treated by splinting who presented with a long-term swan neck deformity (Renfree et al[55]). An additional case of swan neck deformity did occur in Renfree et al's study, but it was excluded from their final data analysis because the patient underwent both splinting and pinning.

Bony versus tendinous mallet finger injuries

It is reasonable to think that management would differ between bony (associated fracture) injuries and tendinous (soft tissue only) injuries. However, outcomes appear to be comparable when the associated fracture is small (<1/3 joint surface). Indeed, most nonsurgical management studies included both small bony and soft tissue injuries without separating them; none of these studies report a difference in outcomes between these 2 injury types. Moreover, Doyle type I injuries do include both isolated tendon injuries and small avulsion fractures. It was not possible to separate them in our analysis, because the vast majority of the studies did not separate out the type, and there would have only been a small number of studies left to evaluate.

Most of the studies regarding surgical management, however, evaluated various operations on only bony mallet fingers; 2 surgical articles also evaluated open suture repair of the tendon plus trans-DIP joint K-wire fixation on isolated tendinous mallet fingers. Our analysis suggests no important differences in postoperative outcomes between these injury types, although we were not able to perform formal statistical tests, because individual patient data were not always reported.

Impact of time from injury to presentation

There remains controversy in the literature regarding the impact that delay from injury and presentation has on outcomes. We excluded all studies investigating exclusively chronic injuries as we aimed to analyze primary treatments rather than salvage procedures. The average time to presentation was less than

28 days in all included studies specifying chronicity of injury. However, many of these articles did include patients with delayed presentation. Including both chronic and acute injuries may affect conclusions drawn from interstudy analyses, but we did not find differences in outcomes. Only one of the surgical articles separates patients who were treated acutely, subacutely, and chronically (>30 d), and the authors found no difference in outcome based on chronicity.[20] Five studies evaluating nonsurgical treatments stratified patients by the time of presentation. Similar to the sole surgical study, none of these studies report any association of outcomes with regard to delay in treatment; 3 studies specifically contend that there was no difference,[38,43,50] whereas the other 2 offered neither statistical analysis nor commentary.[35,37]

Study limitations

This systematic review is limited by the level of evidence and qualities of the studies analyzed. Although most studies did report similar objective criteria to measure treatment outcomes, many studies employed different grading systems. Only 4 of these 44 studies performed power analyses (see Appendix B for nonsurgical articles). Moreover, the lack of congruity in injury type and patient-specific characteristics such as comorbidities further prohibited a meta-analysis. We used weighted means from individual studies for comparison. Certain studies had to be excluded from quantitative comparison if they reported only ranges or categories of treatment results, precluding calculation of a mean value. There were inconsistencies in reporting treatment complications, and when multiple complications occurred in a single case, an accurate complication rate was difficult to determine. Patient adherence to treatment was often not reported, and therefore the efficacy of any treatment modality may not have been accurate.

The majority of the studies included were evidence level IV. Studies with higher evidence levels that did compare 2 or more treatment techniques were small, nonblinded trials that often had substantial loss to follow-up, making them susceptible to detection bias and transfer bias. Selection bias was also present, as many of these studies were retrospective reviews. However, the methodological quality of the studies analyzed in this systematic review was overall quite strong, with a QAT rating of 73.4%—comparable with that of the original study where this tool was employed (mean, 71.3%).[14]

A number of different surgical and nonsurgical treatments of mallet finger injury offer excellent clinical outcomes. Although some splints may be preferred for various reasons, there are no statistically significant differences in outcome. There is a dearth of recent studies that compare surgical with nonsurgical treatments of mallet finger injuries. There remains insufficient evidence to determine when surgical intervention is indicated. Based on our literature review, it appears that these treatments are equivalent and treatment should be individualized to the patient.

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APPENDIX A. Methodological Quality of Operative Studies Assessed by the Quality Appraisal Tool

Study	Item Number; Item Evaluation Criteria* (Maximum = 2; Minimum = 0)											
Authors (Year)	1	2	3	4	5	6	7	8	9	10	11	12	Total (%)
Hamas et al[2] (1978)	2	1	1	0	0	2	2	1	1	1	0	1	50.00
Inoue[15] (1992)	1	2	0	0	1	2	2	0	1	1	0	1	45.83
Bischoff et al[16] (1994)	2	2	1	1	1	2	2	1	1	1	0	1	62.50
Nakamura and Nanjyo[17] (1994)	1	2	1	1	1	2	2	1	2	2	1	2	75.00
Darder-Prats et al[18] (1998)	2	2	1	2	1	2	2	2	2	2	1	2	87.50
Bauze and Bain[19] (1999)	2	1	1	1	1	1	2	2	2	2	2	2	79.17
Takami et al[6] (2000)	2	2	1	1	1	1	2	1	2	1	0	2	66.67
Hofmeister et al[20] (2003)	2	2	2	1	0	2	2	2	2	2	1	2	83.33
Pegoli et al[21] (2003)	2	2	1	1	0	2	2	1	2	1	1	2	70.83
Sorene and Goodwin[22] (2004)	2	2	1	0	1	2	2	1	2	1	0	2	66.67
Teoh and Lee[23] (2007)	1	2	1	1	1	2	2	2	2	2	1	2	79.17
Lee et al[24] (2009)	2	2	2	1	1	2	2	1	1	2	1	2	79.17
Lee et al[25] (2010)	2	2	2	1	0	2	2	2	2	2	1	2	83.33
Kang and Lee[26] (2012)	2	2	1	1	1	2	2	2	2	2	1	2	83.33
Kakinoki et al[27] (2013)	2	2	1	2	0	2	2	2	2	2	1	2	83.33
Miura[28] (2013)	2	1	2	2	0	2	2	2	2	2	2	2	87.50
Neuhaus et al[29] (2013)	2	2	1	1	0	2	2	1	1	1	1	1	62.50
Acar et al[30] (2015)	2	2	2	2	1	2	2	2	2	2	2	2	95.83
Miranda et al[31] (2015)	2	1	1	0	0	2	2	1	2	2	1	1	62.50
Imoto et al[32] (2016)	2	2	1	1	0	2	2	1	1	2	1	1	66.67
Kim et al[33] (2016)	2	2	1	1	1	2	2	1	1	2	1	1	70.83
Zhang et al[34] (2016)	2	2	2	2	1	2	2	2	2	2	1	2	91.67

*Item 1: thorough literature review to define the research question; item 2: specific inclusion/exclusion criteria; item 3: specific hypotheses; item 4: appropriate scope of psychometric properties; item 5: sample size calculation/justification; item 6: appropriate retention/follow-up; item 7: authors referenced specific procedures for administration, scoring, and interpretation of procedures; item 8: measurement techniques were standardized; item 9: data were presented for each hypothesis; item 10: appropriate statistics—point estimate; item 11: appropriate statistical error estimates; item 12: valid conclusions and clinical recommendations.

APPENDIX B. Methodological Quality of Conservative Studies Assessed by the Quality Appraisal Tool

Study	Item Number; Item Evaluation Criteria* (Maximum = 2; Minimum = 0)											
Authors (Year)	1	2	3	4	5	6	7	8	9	10	11	12	Total (%)
Crawford[35] (1984)	0	1	0	0	1	2	1	1	1	1	0	2	41.67
Kinninmonth and Holburn[38] (1986)	2	1	1	0	0	0	2	1	2	1	1	1	50.00
Evans and Weightman[39] (1988)	2	0	1	0	0	1	1	0	1	1	0	1	33.33
Hovgaard and Klareskov[40] (1988)	0	1	1	0	1	0	1	1	1	1	0	1	33.33
Warren et al[37] (1988)	2	2	2	1	0	2	2	2	2	1	1	2	79.17
Shankar and Goring[41] (1992)	2	2	1	1	0	2	2	1	2	2	1	2	75.00
Maitra and Dorani[42] (1993)	2	1	2	1	0	2	1	2	2	2	2	2	79.17
Garberman et al[43] (1994)	2	1	2	1	0	2	2	1	2	2	1	2	75.00
Foucher et al[44] (1996)	1	1	1	0	1	2	2	1	2	1	0	1	54.17
Lester et al[45] (2000)	2	1	1	1	0	2	2	1	2	2	1	2	70.83
Richards et al[46] (2004)	2	2	1	1	0	1	2	2	2	1	1	2	70.83
Kalainov et al[9] (2005)	2	2	2	2	0	2	2	2	2	2	2	2	91.67
Pike et al[47] (2010)	2	2	2	2	2	1	2	2	2	2	2	2	95.83
O'Brien and Bailey[48] (2011)	2	2	2	2	2	1	2	2	2	2	2	2	95.83
Tocco et al[49] (2013)	2	2	2	2	0	2	2	2	2	2	2	2	91.67
Altan et al[50] (2014)	2	2	2	2	2	1	2	2	2	2	1	2	91.67
Saito and Kihara[51] (2016)	2	2	2	2	2	2	2	2	2	2	2	2	100.00

*Item 1: thorough literature review to define the research question; item 2: specific inclusion/exclusion criteria; item 3: specific hypotheses; item 4: appropriate scope of psychometric properties; item 5: Sample size calculation/justification; item 6: appropriate retention/follow-up; item 7: authors referenced specific procedures for administration, scoring, and interpretation of procedures; item 8: measurement techniques were standardized; item 9: data were presented for each hypothesis; item 10: appropriate statistics—point estimate; item 11: appropriate statistical error estimates; item 12: valid conclusions and clinical recommendations.

APPENDIX C. Methodological Quality of Conservative Versus Operative Studies Assessed by the Quality Appraisal Tool

Study	Item Number; Item Evaluation Criteria* (Maximum = 2; Minimum = 0)											
Authors (Year)	1	2	3	4	5	6	7	8	9	10	11	12	Total (%)
Auchincloss[52] (1982)	2	2	2	1	1	1	2	2	2	2	1	2	83.33
Wehbe and Schneider[7] (1984)	2	2	2	1	1	0	2	1	2	2	1	2	75.00
Groebli et al[53] (1987)	2	2	2	1	1	2	2	1	1	1	1	2	75.00
Lubahn[54] (1989)	2	2	0	0	1	2	2	0	1	1	0	1	50.00
Renfree et al[55] (2016)	2	2	2	1	1	2	2	1	2	2	1	2	83.33

*Item 1: thorough literature review to define the research question; item 2: specific inclusion/exclusion criteria; item 3: specific hypotheses; item 4: appropriate scope of psychometric properties; item 5: sample size calculation/justification; item 6: appropriate retention/follow-up; item 7: authors referenced specific procedures for administration, scoring, and interpretation of procedures; item 8: measurement techniques were standardized; item 9: data were presented for each hypothesis; item 10: appropriate statistics—point estimate; item 11: appropriate statistical error estimates; item 12: valid conclusions and clinical recommendations.