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Original Research

# Defining Nonunion for Metacarpal Fractures: A Systematic Review

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*Purpose:* Our purpose was to assess how nonunion of the metacarpals has been defined in prior investigations with respect to both clinical and radiographic criteria. We hypothesized that the definitions of nonunion would be highly variable.

*Methods:* A systematic review was conducted using MEDLINE and Embase databases for clinical articles related to the treatment of metacarpal fractures (surgical and nonsurgical) from 2010 to 2021. Included articles were searched to assess how nonunion was defined based on clinical and radiographic criteria. We assessed the treatment type, method of union assessment, time to union, and incidence of union as well as article factors such as the following: date of publication, level of evidence, and publishing journal.

*Results:* A total of 641 articles were identified, of which 102 were included for a definition of nonunion and 97 were included for the assessment of clinical management and outcomes. Of the included articles, 62% contained level IV evidence. A definition of nonunion was provided in 47% of the articles. Radiographic criteria alone, clinical criteria alone, or a combination of the 2 was used in 22%, 6%, and 19% of the cases, respectively, to define nonunion. The most common definition of nonunion was presence of fracture-site tenderness (with no time defined) in 20 articles (20%), followed by lack of radiographic healing at 6 months (15%). In the 97 included articles, the total number of fracture cases was 4,435 and nonunion was reported in 0.45%. Cases with nonunion were reported in a total of six articles that used a variety of treatment modalities.

*Conclusions:* The definition of metacarpal nonunion remains highly variable and lacks standardization with respect to clinical and radiographic criteria.

*Clinical relevance:* Standardizing the definition of nonunion for metacarpal fractures would allow for more accurate assessments of the incidence of this complication and may aid in improving diagnostic and management strategies.



Metacarpal fractures remain one of the most common reasons for patients to visit the emergency department.[1–3] Around 1% of emergency department visits are due to a fracture in the hand, and over 40% involve metacarpal or phalangeal fractures.[1–3] Metacarpal fractures are more common in men and often occur between the ages of 20 and 30 years.[1–3] They are also more common among athletes, particularly in those involved in contact sports.[4] Metacarpal fractures can occur in isolation at the head, neck, shaft, or base or can be part of a multi-injury complex. The force directed on the digit at the time of the injury often determines the specific fracture pattern. With both surgical and nonsurgical treatment, stiffness and malunion remain among the most common complications.[5,6]

Metacarpal nonunions are rare clinical entities.[5] Broadly, nonunions can be categorized as atrophic, hypertrophic, or oligotrophic, with most nonunions in the metacarpals defined as atrophic.[5] Nonunions can occur because of inadequate fixation or biological causes related to patient comorbidities, infection, lack of blood supply, and poor soft tissue envelopes.[5] Most often, nonunions in metacarpal fractures occur in transverse fracture patterns, with an incidence of around 30%.[7] The definition of metacarpal nonunion remains highly variable, and there is no definitive timeline used. Prior authors have described metacarpal nonunions using both clinical and radiographic criteria.[5,8–10]

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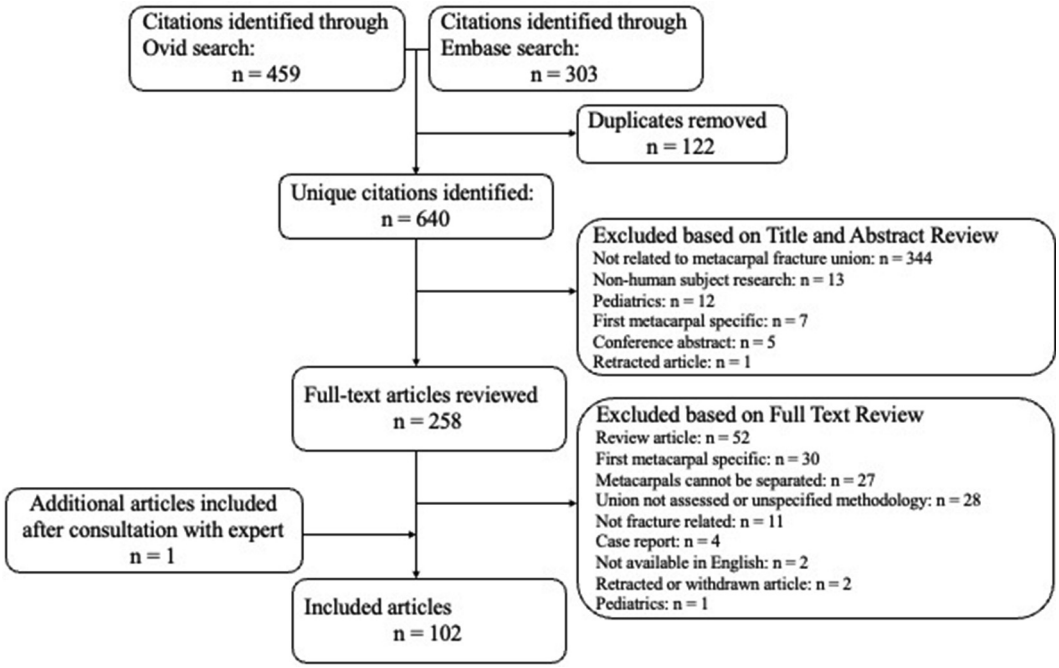


**Figure.** Article review process following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Although rare, symptomatic metacarpal nonunions can result in both pain and joint stiffness, both of which can result in functional limitations. In the setting of nonunion, surgical treatment becomes more complicated because it often includes revision fixation with autograft bone harvest.[11] Lack of standardization with respect to definition of nonunion can make it challenging to study the true incidence and hinders evidence-based guidance for the indications and timing of surgical treatment. The purpose of this investigation was to assess how nonunion of the metacarpals has been previously described in prior series with respect to clinical and radiographic criteria. In addition, we aimed to determine the incidence of metacarpal nonunion through a systematic review. We hypothesized that the definition of nonunion from prior investigations would be highly variable.

## Methods

Institutional review board exemption was obtained for this study. This investigation adhered to the Preferred Reporting Systems for Systematic Reviews and Meta-Analyses.[12]

### *Article eligibility*

This review focused on the definitions of nonunion in the treatment of metacarpal fractures in the current literature. We included articles published between January 1, 2010, and June 1, 2021. Publications were excluded if they were not related to metacarpal fractures, fracture healing was not measured or reported, they focused on the first metacarpal, the methodology of treatment or assessment of the metacarpals could not be separated from other included anatomy (first metacarpal, phalanges, carpals, radius, etc), they contained only pediatric patients or pediatric patients could not be separated, or the study did not involve human subjects. Articles published in a language other than English were also excluded. For the primary aim of this study (definition nonunion), all nonoriginal research articles, including systematic reviews, meta-analyses, editorials, case reports, and expert opinion articles, were read in full and excluded only if no definition for union or nonunion was used. Reviewers (D.S.H., C.C., J.E.K.) were generous in their assessment of the definition of nonunion and included articles if any attempt to define nonunion was provided. For our secondary aim, only clinical articles were included for the assessment of the incidence of metacarpal nonunion.

### *Search strategy*

A literature search was developed by an institutional clinical informatics specialist and conducted in June 2021. The search criteria for Ovid MEDLINE and Embase databases are outlined in Appendix 1 (available on the *Journal*'s website at www.jhsgo.org). Prior to extracting citations, initial screening performed by the clinical informatics specialist excluded biomechanical, cadaveric, and nonhuman research animal studies. The screening details of extracted citations are included in the Figure. Abstracts and citations for articles were screened for eligibility by two independent authors (D.S.H., C.C.). Three authors (D.S.H., C.C., J.E.K.) independently reviewed the full text of the remaining articles and resolved any discrepancies through discussion. For abstracts, full-text review, and data extraction, if agreement by consensus could not be reached, any disagreement was resolved through consultation with the senior author (L.C.G.).

### *Data extraction*

Included articles were searched for the use and definition of the term nonunion and clinical factors related to the treatment, radiographic assessment, and rate of union. The definition-based assessment included the presence or explanation of nonunion and whether the definition contained a clinical or radiographic component. When a definition was found, it was included and analyzed as originally written. A separate record was kept if union was assessed and if it was assessed clinically, radiographically, or

**Table 1**
Article Characteristics for all Included Studies Involving the Treatment of Metacarpal Fractures

| Total Studies Included, n | 102 |
|---|---|
| LOE, n (%) | |
| I | 1 (1) |
| II | 18 (17) |
| III | 20 (20) |
| IV | 63 (62) |
| Treatment method, n (%) | |
| K-wire | 43 (42) |
| Mixed | 27 (26) |
| Plate and screws | 12 (12) |
| Screws | 11 (11) |
| Other | 5 (5) |
| Nonsurgical | 4 (4) |
| Journals, n (%) | |
| *Hand* | 8 (8) |
| *Journal of Hand Surgery: European Volume* | 7 (7) |
| *The Journal of Hand Surgery Asian-Pacific* | 5 (5) |
| *Hand Surgery and Rehabilitation* | 6 (6) |
| Years of publication, n (%) | |
| 2010–2012 | 17 (17) |
| 2013–2015 | 22 (22) |
| 2016–2018 | 26 (25) |
| 2019–2021 | 37 (36) |
| Nonunion defined, n (%) | 47 (47) |
| Clinical | 6 (6) |
| Radiologic | 22 (22) |
| Both | 19 (19) |
| Union assessed, n (%) | 96 (94) |
| Clinical | 3 (3) |
| Radiologic | 54 (53) |
| Both | 32 (31) |
| N/A | 7 (7) |

N/A, not applicable.

both. Article information, including date of publication, level of evidence (LOE), and publishing journal, was also extracted.

### *Statistics*

Descriptive statistics were used for this investigation.

## Results

A total of 640 articles were identified from the databases searched. One additional article was identified after consulting with the senior author (L.C.G.). Of these, 102 articles were included in the final analysis for the primary aim (definition of nonunion). For the secondary aim (incidence of nonunion), 5 articles were excluded before analyzing the case numbers because phalangeal and metacarpal fractures could not be separated, leaving 97 articles available for the assessment of the types of treatment and rates of union. Table 1 summarizes the study characteristics. More than half of the articles included were case series (62%), followed by case-control comparisons (20%). Assessment of union was included in 94% of the articles, with 84% relying on radiographic criteria either solely or in combination with clinical criteria.

Nonunion was defined in only 47% of the articles, with reliance on clinical, radiographic, or a combination of both in 6%, 22%, and 19%, respectively (Table 1). The most commonly used definitions of nonunion are reported in Table 2. Among the studies that provided a definition of nonunion, the most frequently employed was clinical in nature, with 20% of the studies defining nonunion as the presence of fracture-site tenderness. The second most used (and the most commonly defined radiographic criterion) was lack of bony healing at 6 months from the time of injury (15%).

**Table 2**
Definitions of Nonunion Used in Included Articles

| Definition of Nonunion | Number of Articles Using Definition, n (%) |
|---|---|
| Undefined | 55 (53) |
| Presence of fracture-site tenderness, time undefined | 20 (20) |
| Lack of radiologic bony healing at 6 mo | 15 (15) |
| Absence of a minimum of three cortices of bridging callus, time undefined | 10 (10) |
| Absence of bridging bone callus on plain radiography, time undefined | 8 (8) |
| Presence of motion at the fracture site, time undefined | 3 (3) |
| Lack of radiologic bony healing at 4 mo | 3 (3) |
| Absence of signs of progressive healing on consecutive radiographs for a period of 4–6 mo | 1 (1) |
| Presence of radiographic fracture line at 14 mo | 1 (1) |
| Inability to actively move the fractured digit by 50% of range of motion painlessly, time undefined | 1 (1) |
| Absence of callus formation on ultrasound, time undefined | 1 (1) |

**Table 3**
Classification of Studies According to Time to Fracture Union

| Time to Union (wk) | Total Number of Studies (Studies With Nonunion) | Mean Time to Union ± SD (wk) |
|---|---|---|
| ≤6 | 36 (2) | 5.2 ± 0.9 |
| 6 to ≤12 | 23 (3) | 9.2 ± 2.2 |
| >12 | 4 | 21.7 ± 4.4 |
| Unknown | 34 (1) | |

Table 3 includes a comparison of article characteristics relative to the time to fracture union. Sixty-three articles included the time to fracture union, with the majority (n = 36) reporting a time to union shorter than 6 weeks (mean, 5.2 ± 0.9 weeks). Twenty-three articles reported a time to union between 6 and 12 weeks, with a mean of 9.2 ± 2.2 weeks. Only 4 articles had a time of union exceeding 12 weeks.

For the assessment of union rates (97 included articles), the total number of reported cases was 4,435. Of those, a total of 20 cases were found to have metacarpal nonunions (0.45%). Cases with nonunions were reported in a total of six articles (Table 4) that used a variety of treatment modalities. In these studies that reported a nonunion, the percentage ranged from 1.4% to 7.8%. The remaining 91 articles reported no cases of nonunion. No studies reporting cases of nonunion used computerized tomography or magnetic resonance imaging as part of the assessment of union.

## Discussion

This systematic review focused on studies describing clinical outcomes and treatment modalities for metacarpal fractures in an effort to understand the clinical and radiographic definitions of metacarpal nonunion. Less than half of the included studies (47%) contained a specific definition of this complication. When defined, we found considerable variance in the criteria used for nonunion, with up to 10 different radiographic and clinical definitions identified. It is important to note that even the most frequently used definition was only present in 20% of the articles. Our results indicate the lack of a standardized definition for metacarpal nonunion in the current literature. This finding is not unique to metacarpal literature because there appears to be a similar lack of standardization for the definition of nonunion in radius and other long-bone fractures.[19,20] Recent studies continue to show that lack of consensus in diagnosing and defining fracture nonunion is common.[19,21,22] This is further complicated by the fact that existing

**Table 4**
Characteristics of Studies With Metacarpal Nonunion Cases

| Author | Year | Country | LOE | Fixation Type Used in Nonunited Fractures | Number of Fractures | Number of Nonunions | Percentage of nonunion (%) |
|---|---|---|---|---|---|---|---|
| Abulsoud et al[13] | 2021 | Egypt | 4 | K-wire | 23 | 1 | 4.3 |
| El-Hadidy et al[14] | 2019 | Egypt | 2 | Mixed | 154 | 12 | 7.8 |
| Ghosh et al[15] | 2013 | India | 2 | K-wire | 19 | 1 | 5.3 |
| Ali et al[16] | 2020 | Pakistan | 2 | K-wire | 50 | 1 | 2 |
| Van Bussel et al[17] | 2020 | Netherlands | 4 | K-wire | 51 | 4 | 7.8 |
| Vasilakis et al[18] | 2019 | USA | 3 | Lag screw | 70 | 1 | 1.4 |

USA, United States of America.

definitions rely on different criteria that can be radiographic, clinical, or both.[23] Having a standardized definition of nonunion would not only aid in accurately assessing the incidence of this complication but may also help in developing diagnostic and management strategies.

In our review, more studies provided radiographic as opposed to clinical definitions of nonunion (22% vs 6%, respectively), with 19% of the included articles using a combination of both. When the specific definition of fracture union in the included articles was assessed, 84% of the studies relied on radiographs, either alone or in combination with clinical examination, compared with only 34% of the studies that included a clinical component to determine that a fracture has united on follow-up. In a review of 74 articles on long-bone nonunion, Wittauer et al[19] similarly noted that radiographic criteria were more frequently used than clinical criteria (62% vs 44%, respectively). They also found a comparable rate of articles presenting a formal definition of nonunion, with only half of the reviewed articles containing any definition. The time interval from diagnosis to nonunion was inconsistently defined, ranging from less than 6 weeks to more than 3 months (Table 3). This may impact the management and outcomes of these fractures by affecting the timing of interventions. For this reason, several European groups have suggested a more pragmatic definition of nonunion, which is a fracture that does not consolidate without any further intervention, independent from the treatment time.[24,25]

Based on our results, six articles included metrics regarding the rate of nonunion among their population. Although the overall rate of nonunion in this systematic review was 0.45%, among articles that had cases of nonunion, the rate of nonunion averaged 5.4% (range, 1.4%–7.8%). Articles assessing nonunion of other fractures, such as those in the tibia and scaphoid, also demonstrate variability in the rate of nonunion after fixation. Tibial fractures demonstrate nonunion rates varying from 5% to 33%.[26–28] The rates of scaphoid nonunion are also wide ranging between 5% and 62% depending on the location of the fracture and method of treatment.[29,30] In this context, the lack of definition standardization creates a two-fold problem. When the definition of nonunion is variable, it becomes more difficult to accurately define the incidence.

For the 102 studies that met the inclusion criteria, the overall LOE was low, with 63 studies (62%) classified as level IV. Other systematic reviews assessing the nonunion characteristics of non-metacarpal fractures showed varying distributions of LOE as well. For tibial fractures, reviews included 3 level IV (15%), 7 level III (35%), and 10 level II (50%) studies.[31,32] For scaphoid fractures, selected reviews included three level IV (18%), four level III (24%), six level II (35%), and four level I (24%) studies.[33,34] In addition to variable LOE for studies assessing metacarpal fractures, we also found substantial variability with respect to fixation methods used among the included articles. K-wire fixation was the most common (42%), followed by a mixed fixation method (26%). In addition to a non-standardized definition, study heterogeneity with respect to fracture location and treatment methods may contribute to differences in the reported rates of nonunion.[29] This review is not without additional limitations. There were a limited number of high-LOE articles, and only six of the included articles reported any cases of nonunion (20 total cases). This may have influenced the overall rate of nonunion. In addition, there may have been a publication bias in submitting or publishing series that reported higher-than-expected rates of nonunion. Again, lack of study homogeneity may have impacted our results because of overall low evidence quality and heterogeneous treatment methods. Considering our aims and methodology, this investigation cannot make a definitive recommendation regarding the definition of nonunion for these injuries.

Based on the definitions used in prior clinical investigations, the definition of metacarpal nonunion remains highly variable and lacks standardization. In this systematic review of clinical studies involving the treatment of metacarpal fractures, 53% of the articles did not formally define nonunion. When defined, the presence of fracture-site tenderness was the most common criterion used (20%), followed by lack of radiographic osseous union at 6 months (15%). The overall LOE for the included studies was low, and the reported incidence of nonunion was 0.45%. Standardizing the definition of nonunion for metacarpal fractures would allow for more accurate assessments of the incidence of this complication and may aid in improving diagnostic and management strategies for metacarpal fractures.

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