Arthrodesis of the proximal interphalangeal joint of the finger – a systematic review

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• Arthrodesis of the proximal interphalangeal (PIP) joint of the finger is an established procedure for advanced osteoarthritis. As there are different techniques of fusion, it seems necessary to evaluate the results.
• Primary outcome of this review was to evaluate different arthrodesis methods of the PIP joint and describe different numbers of non-unions. Secondary outcome was to evaluate time to consolidation. Respective complications, if mentioned, were listed additionally.
• The review process was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The selected databases were PubMed, Medline, Embase, Google Scholar and Cochrane Library. Studies reporting outcomes of the arthrodesis with a defined technique and radiological consolidation were included. Complication rates and types were recorded. In total, 6162 articles could be identified, 159 full-texts were assessed and 64 studies were included. Methodological quality was assessed using Methodological Index for Non-Randomized Studies.
• A total of 1923 arthrodeses of the PIP joint could be identified. Twelve different surgical techniques were described, four of these techniques with compression at the arthrodesis site. The most frequently used techniques were K-wires (n = 743, 14 studies), tension-band (n = 313, 15 studies) and compression screws (n = 233, 12 studies). The lowest rate of described non-unions in compression techniques was 3.9% with the compression screw. The highest non-union rate of 8.6% was achieved by interosseous wiring.
• All the described techniques can achieve the goal of fusing an osteoarthritic joint. There is a tendency in the more recent literature for the use of compression techniques.

Introduction

Osteoarthritis of the proximal interphalangeal (PIP) joint, either primary or secondary, limits the range of motion and causes pain with or without instability, leading to significant global hand function impairment (1). Typical aetiologies leading to secondary osteoarthritis are posttraumatic changes, chronic instability or inflammatory diseases, for example rheumatoid arthritis or scleroderma. Operative treatment options include denervation, different arthroplasties, prosthesis or arthrodesis. The aim of arthrodeses is pain reduction in combination with a sufficient global hand function (2). With distinctive deformation of the joint and/or preexisting instability, there is a tendency to recommend arthrodesis because an unstable prothesis is prone to failure. In these cases, the fusion of the joint provides reliable results.

In posttraumatic osteoarthritis, especially of the radial digits with an instability not exceeding 30°, a prothesis could provide excellent results (3, 4). If more than one
joint is affected, especially in patients with rheumatoid arthritis, and only a moderate instability exists, silicone arthroplasty is still the method of choice (5).

Arthrodesis of the PIP joint is an established technique for advanced osteoarthritis or when other reconstruction methods have failed. Different techniques for arthrodesis of the PIP joint have been described and their main difference is if there is compression on the arthrodesis or not (6). There is no clear indication in the current literature as to which technique shows the most promising results in terms of union. Typical major complications of PIP joint arthrodesis are non-union and mal-union; minor complications are superficial infections (61).

The aim of this first systematic review was to clarify the following questions: Do different arthrodesis methods of the PIP joint for primary and secondary causes of osteoarthritis or destruction of the joint show (i) different numbers of non-unions? (primary outcome) and (ii) different times to consolidation? (secondary outcome). The different complications of each technique were additionally included but not further evaluated.

**Methods**

**Search methods**

The review process was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (7). Two reviewers (MM and HV) independently selected studies for inclusion. Disagreements were solved by discussion with a senior author (MR).

The search was conducted from January 1, 1946, to April 28, 2020, in the following databases: PubMed, Medline, Embase, Google Scholar and Cochrane Library by the main author. We initially searched without any language or publication type restrictions. The search algorithm is shown in Table 1.

**Selection criteria**

Full-text reports (original articles, randomized controlled trials, controlled clinical trials, retrospective or prospective observational studies, case series and technical descriptions) concerning PIP joint arthrodesis were screened.

Reference lists from included studies and reviews were screened for additional studies and included. Studies reporting outcomes of the arthrodesis with a defined technique and radiological consolidation were included. Complication rates and types were recorded. Clinical studies with an evidence level of I–IV were included. As there were studies which compared arthrodeses to other techniques of joint salvage, those reporting of five or less arthrodeses were also included.

Studies lacking original data, studies whose data were not doubtlessly concerning the PIP joint as well as studies whose full-text were not available were excluded. Doctoral theses were also excluded.

The search flowchart according to the PRISMA guidelines is depicted in Fig. 1. Initially, 6162 articles were identified. Thirteen additional records from reference lists were included. After removing 1914 duplicates, 4261 articles remained. By screening titles and abstracts, a further 4102 studies were excluded.

The full text of 159 articles was thoroughly assessed and evaluated for reporting the number of treated PIP joints, the technique used and the primary endpoint of consolidation. The 64 studies depicted in Table 2 were finally included, and data were extracted from these based on the inclusion criteria. Six studies that focused on diseases of connective tissue, for example rheumatoid arthritis, were mentioned separately from other indications.

**Data extraction**

Data were extracted from the included studies by two authors independently (MM and HV) according to a predefined data extraction sheet. The level of evidence, quality and risk of bias assessed with the standardized critical appraisal instrument, Methodological Index for Non-Randomized Studies (MINORS) score, where applicable, were recorded (8). The methodological quality score MINORS shows a mean of 8 with a global ideal score of 16. Fifty-five articles had level IV evidence, and nine articles had level III evidence. Nearly all studies were retrospective data analysis. We extracted the number of PIP joint arthrodesis, the technique used, time of immobilization, number of non-unions, time to radiological consolidation, and the incidence and type of complications. All patients regardless of their age with arthrodesis were included in this review.

**Table 1** The respective search string of the different included databases.

| Database            | Search string                                                                 |
|---------------------|-------------------------------------------------------------------------------|
| Pubmed              | (((proximal interphalangeal joint[Title/Abstract]) OR (pipj[Title/Abstract]) OR (pip-joint[Title/Abstract]) OR (finger[Title/Abstract]) OR (digital[Title/Abstract]) OR (pip[Title/Abstract]) OR (proximal interphalangeal[Title/Abstract]) AND (arthrodesis[Title/Abstract]) OR (fusion[Title/Abstract])) NOT equine[Title/Abstract] |
| Embase              | (`proximal interphalangeal joint'/exp OR pij:ab,ti OR `pip joint':ab,ti OR `proximal interphalangeal joint':ti,ab OR `digital':ab,ti OR `finger':ab,ti) AND (`arthrodesis':ti,ab OR `fusion':ab,ti) AND (embase)/lim |
| Cochrane Library    | (pip OR pip-joint OR pij-joint OR proximal-interphalangeal-joint OR proximal interphalangeal-joint OR digital OR finger) AND (arthrodese OR fusion) allintitle: (`pip" OR "pip joint" OR "proximal interphalangeal joint" OR "digital" OR "finger") AND ("arthrodese" OR "fusion") |
| Google Scholar      | (pip OR pip-joint OR pij-joint OR proximal-interphalangeal-joint OR proximal interphalangeal-joint OR digital OR finger) AND (arthrodese OR fusion) allintitle: (`pip" OR "pip joint" OR "proximal interphalangeal joint" OR "digital" OR "finger") AND ("arthrodese" OR "fusion") |
Table 2

The included studies cover a time span of 74 years of studies) and compression screws (K-wires (n = 6162). Cochrane Library = 3021 database searching Embase = 3021 Google Scholar = 25 through other sources = 13

Included studies

A total of 1923 arthrodeses of the PIP joint could be extracted from the included papers (Table 2). The main indications for the arthrodesis of the PIP joint were primary or secondary osteoarthritis, joint infection or traumatic destruction. Included are six studies that consisted only of patients with rheumatic disease, for example rheumatoid arthritis or systemic sclerosis. These results are presented separately in Table 2.

Surgical techniques

Twelve different surgical techniques were described. Four of these techniques with compression at the arthrodesis site: interosseus wiring with/without K-wire, tension-band, cannulated screw as well as a lag screw – combined a total of 805 arthrodeses. The plate, external fixation and K-wire might hold some applied compression during the arthrodesis but do not hold any compression potential themselves. The most frequently used techniques were, with the number of arthrodesis in descending order, K-wires (n = 743, 14 studies), tension-band (n = 313, 15 studies) and compression screws (n = 233, 12 studies). The included studies cover a time span of 74 years of publication, and that there is an obvious trend towards techniques with compression of the arthrodesis, especially with compression screws.

Non-unions and mean consolidation times

Non-unions were reported in all studies. Two studies included other finger joints besides the PIP and did not report the exact numbers of non-unions concerning the fused joint. In these cases, the studies were only included for the consolidation time, for they reported that explicitly. The lowest non-union rate in compression techniques was 3.9% with the compression screw. Interestingly, the non-union rate for the peg fixations (without compression) was even lower 3.6%. The highest non-union rate showed the interosseous wiring with 8.6% (Table 3).

Table 4 depicts the mean consolidation times. Further information on how non-unions were stratified by technique is presented in the Supplementary information and the results are presented in supplementary figures 1 and 2.

Complications

Four studies did not describe complications. All others either stated that they had no complications or did not describe them in detail. Most complications besides the non-unions were infections (mostly superficial), pain caused by the implant or mal-unions. The consequences of these complications, that is, if revisionary surgery had to be performed or if superficial infections could be treated by antibiotics, were not reported.

Discussion

A wide range of different surgical techniques for achieving fusion of the PIP joint have been published. Moberg already stated in 1960 that ‘the prime requisite of a good digital arthrodesis is a painless and stable union in proper position occurring in a reasonable space of time’ (39). Nevertheless, a proper comparison, although needed, proves to be difficult because of the variable quality of published studies, different indications for joint fusion, varying definitions of consolidation (radiological vs clinical) as well as lacking important data in large but older studies, where a personal communication with the author is no longer possible (73).

The two main groups of joint fusion techniques which can be differentiated, are techniques with and without compression of the arthrodesis site respectively (6). The most important advantage of the compression is the assumed shorter consolidation time because of higher primary stability, consolidation by primam intentionem with fewer non-unions as well as early functional occupational therapy (60, 64).
### Table 2: Studies of arthrodeses of the PIP joint of the finger with different techniques.

| Reference | Year | LoE | MINORS score | Technique | Arthrodeses, n | Non-union, n | Consolidation (t) | Finger | IMM (t) | PROM (type, data) | Complications (Y/N) |
|-----------|------|-----|--------------|-----------|----------------|--------------|-------------------|--------|---------|-------------------|----------------------|
| Al-Qattan (9) | 2016 | N   | 11           | Interosseous + K-wire | 5 | 0 | 5 weeks | 5 × DII | NR | NR | N | Y – Lateral deviation; infection |
| Allende & Engleman (10) | 1980 | N   | 8            | Tension-band | 16 | 0 | 4–6 weeks | 5 × DII, 3 × DII, 4 × DIV, 3 × DV | NR | NR | N |  |
| Arata et al. (11) | 2003 | N   | 9            | Bioabsorbable rod | 1 | 0 | 7.9 weeks | NR | 2 × DII | NR | 3–4 weeks | NR | N | Y – 4x fracture dorsal cortex, 2x pain |
| Ayres et al. (12) | 1988 | N   | 10           | Herbert screw | 51 | 1 | 6 weeks | NR | 2 × DII | NR | 3 weeks | NR | N |  |
| Bansky & Racz (13) | 2005 | N   | 3            | Plate | 2 | 0 | NR | 2 × DII | NR | 3 weeks | NR |  |
| Baruch & Kahanovich (14) | 1980 | N   | 4            | Angulated bone peg | 5 | 0 | NR | 2 × DII | NR | 3 weeks | NR | N |  |
| Biskop (15) | 1985 | N   | 11           | Tension-band | 25 | 0 | 12 weeks | 7 × DII, 5 × DII, 9 × DIV, 4 × DV | – | NR | N | Y – 2x inflammation |
| Breyer et al. (16) | 2015 | III | 10           | Tension-band | 24 | 2 | 9.4 weeks | NR | 2–3 weeks | NR |  |
| Buechler & Alken (17) | 1987 | N   | 10           | Bone graft and plate | 25 | 2 | 45–90 days | 5 × DII, 13 DIII, 6 DIV, 1 DV | NR | NR | TAM | Y – 2x superficial infection |
| Buck-Gramcko & Oehme (18) | 1988 | III | 6            | Interosseus + K-wire | 84 | NR | 7 weeks | NR | 2–3 weeks | NR |  |
| Burton et al. (19) | 1986 | N   | 12           | Lag screw | 6 | NR | 8.1 weeks | NR | NR | TAM |  |
| Carroll & Hill (20) | 1969 | N   | 6            | Cup/cone + K-wire | 230 | 9 | 6–8 weeks | NR | 6–8 weeks | NR |  |
| Faithfull & Herbert (21) | 1984 | N   | 4            | Lag screw | 5 | 0 | NR | NR | – | NR | N |  |
| Goth & Konigsberger (22) | 1976 | N   | 9            | Lag screw | 20 | NR | 8.2 weeks | NR | NR | TAM |  |
| Harrison & Nicolle (23) | 1974 | N   | 2            | Harrison–Nicolle peg | 51 | 0 | 10.6 weeks | NR | 3–4 weeks | NR |  |
| Herzog (24) | 1961 | N   | 5            | Bone peg | 35 | 1 | 9.2 weeks | NR | 3–4 weeks | NR |  |
| Hoffmann & Rossack (25) | 1975 | N   | 6            | External fixation | 23 | NR | 8 weeks | NR | 6 weeks | TAM | Y – 2x delayed union, 1x arterial spasm |
| Høeg & Jensen (26) | 1982 | N   | 9            | Interosseus + K-wire | 23 | NR | 8 weeks | NR | 6 weeks | TAM | Y – 2x infection, 1x pain with amputation |
| Hohendorff et al. (27) | 2016 | N   | 9            | Tension-band | 16 | 1 | 6 weeks | 5 × DII, 4 × DII, 6 × DIV, 6 × DV | 6 weeks | Pain VAS, DASH, PS |  |
| Jones et al. (28) | 2011 | III | 8            | K-wires | 2 | 1 | 9 months | 1 × DII, 1 × DIV, 4 × DII, 4 × DV | NR | NR | MHOQ | Y – 2x malunion |
| Khuri (29) | 1986 | N   | 8            | Tension-band | 10 | 0 | 10 weeks | 1 × DV | NR | 7–10 days | NR | N |  |
| Kowalski & Manske (30) | 1988 | N   | 10           | K-wires | 6 | 0 | 6–12 weeks | 2 × DII, 2 × DIV, 2 × DV | 6 weeks | NR | N |  |
| Study | Year | Methods | Duration | Complications |
|-------|------|---------|----------|---------------|
| et al. | 2012 | Compression screw | 6 weeks | NR |
| et al. | 2019 | Interosseus wiring | 6 weeks | NR |
| et al. | 1991 | Steinmann pin | 8 weeks | NR |
| et al. | 2005 | Interosseus + K-wire | 6 weeks | NR |
| et al. | 2004 | Interosseus + Steinmann pin | 6 weeks | NR |
| et al. | 2006 | Interosseus + K-wire | 6 weeks | NR |
| et al. | 2001 | Interosseus + Steinmann pin | 6 weeks | NR |

(Continued)
The assumption that techniques with compression are more reliable, as demonstrated by Leibovic in 1994, could not be clearly proven (32). One possible reason might be that the compression techniques are surgically more difficult and might tend to non-union if there are no ideal operative results. For example, there is the possibility that a tension-band fusion does not apply the compression to the whole arthrodesis site and therefore renders it unstable. The compression screw however might be easier and more forgiving to implant than tension-band or intraosseus wiring. That might be the reason why the superiority of this implant in contrast to K-wires is evident in different studies in the literature (32, 36).

Nevertheless, in the studies included in this systematic review, there is a trend towards techniques with compression over the course of time, especially towards compression screws (41, 42). With further development of the implants, the diameter of the screws got progressively smaller, as 8 mm diameter screws are commercially available now. Thus, these days they can be used in small bones too.

Newer implants like the Apex IP fusion device so far lack any evidence that they are easier to implant or provide a better outcome, maybe because they have not been available in the market long enough (42).

The most reported complications besides the primary outcome of non-unions were infection, mostly superficial.
As there is typically very little soft tissue around the PIP joint, protruding implants, like a tension-band, can cause irritation and subsequently a superficial infection. This emphasizes the need for a proper handling of soft tissues (36).

Rheumatoid arthritis and connective tissue diseases
Rheumatoid inflammatory diseases commonly affect the joint, especially the PIP joint, which may lead to contractures and deviations that are both disabling as well as cosmetically unacceptable (74). These diseases could affect the quality of the bones and therefore the stability of arthrodeses as well as the healing of soft tissues. The referenced papers by Gilbart et al. (69), Jones et al. (71) and Lipscomb et al. (72) relate to patients with systemic sclerosis. From a pragmatic point of view, one might state that if something works for this challenging group of patients it will probably work for a patient with osteoarthritis. Interestingly and somewhat counterintuitively, Lipscomb et al. (72) found quicker healing compared to other studies dealing with posttraumatic osteoarthritis.

Biomechanical properties and primary stability
The primary stability of different fusion techniques or implants could provide an interesting insight into the ability of the implant itself to withstand the forces of early function therapy as well as a short or even no immobilization. There are only a few papers that have tried to compare the results of different biomechanical studies (75, 76). Therefore, it seems reasonable to conduct a biomechanical study for comparing the different implants and techniques of interphalangeal arthrodesis so that postsurgical treatment can be standardized.

Strengths and limitations
There are several limitations of the existing literature as well as of this study. In order to do a reasonable meta-analysis and statistical evaluation of the different techniques, randomized controlled trials (RCT) are required. On the topic of arthrodesis of the PIP joint, there is no RCT published at all. Therefore, we did a qualitative systematic review with only descriptive data pooling of the different studies with respect to their published technique for greater clearness instead of a meta-analysis. Another limitation is that the literature review for this systematic review showed that there are predominantly studies with an evidence level IV, with a heterogenous MINORS score but a satisfying mean of 8. As the risk of bias as depicted in the MINORS score exists, one might suspect that the published technique makes the apparent effect appear better than it is. There were nine evidence level III studies which could be included. Nevertheless, these results imply a lack of good quality data to statistically compare the different techniques and to achieve recommendations. Especially the complications of different techniques, which we extracted from the studies, were reported very heterogeneously with no clear evidence on how to avoid them or of their consequences.

Strengths of this systematic review is its novelty and uniqueness, since there are no systematic reviews with a high quality, like PRISMA methodology. It includes a very long-time span of nearly 74 years and covers the most extensive databases. A very large number of abstracts were screened to achieve the most complete systematic review.

Conclusion
The compression screw shows superior results with respect to non-unions in comparison to K-wires. There is a tendency of more published techniques with compression in the last 10 years which might implicate a shift towards compression techniques. Given the limited evidence of the available studies on arthrodesis of the PIP joint, there is a lack of clear indications for other special techniques. The three most often used techniques are K-wires, tension-band and compression screws. The K-wires still have their place in acute trauma with soft tissue defects or replantation. Only large multi-center RCTs can answer the question on which technique for arthrodesis of the PIP joint is the best.

Supplementary materials
This is linked to the online version of the paper at https://doi.org/10.1530/EOR-21-0102.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the work reported here.

Funding Statement
This work did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector.

Author contribution statement
H-C Vonderlind and M Ruettermann: both authors contributed equally to this manuscript.

Acknowledgements
The authors would like to thank Stefanie Karpik for her support in preparing and correcting the manuscript with respect to spelling and grammar.
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