Systematic Review

Host Factors and Risk of Pin Site Infection In External Fixation: A Systematic Review Examining Age, Body Mass Index, Smoking, and Comorbidities Including Diabetes

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Abstract

Introduction: Host factors affecting pin site infections were selected by The Pin site Consensus Group, using a modified Delphi approach, to be one of the top 10 priorities to investigate how to reduce rates of pin site infections, improve clinical management, and inform research. The aim of this study was to perform a systematic literature review of the association between host factors and pin site infection, focused on age, smoking, body mass index, and comorbidities, in particular diabetes. **Materials and Methods:** The literature search strategy was developed as advised in the *Cochrane Handbook for Systematic Reviews of Interventions* following the PRISMA guidelines with the help from a scientific librarian. The protocol was registered in the International Register of Systematic Reviews, PROSPERO (ID: CRD42021273305). The literature search was executed in three electronic bibliographic databases, including Embase MEDLINE (1111 hits) and CINAHL (2066 hits) through Ovid and Cochrane Library CENTRAL (387 hits). **Results:** A total of 3564 titles were found. 3162 records were excluded by title and abstract screening. 140 studies were assessed for full-text eligibility. All excluded studies were not reporting specific numbers of patients with pin site infection and the associations of interest. 11 studies were included for data extraction. The included studies were all designed retrospective, and the risk of bias assessment was done using Joanna Briggs Institute risk appraisal tool. The extracted data are presented as results in tabular summaries. This review reveals an increased risk of pin site infection associated with increased HbA1C level in diabetic patients and congestive heart failure in diabetic patients. An increased risk of pin site infection was associated with a lower ASA score. None of the included studies found any association between pin site infection and smoking, age, or body mass index. **Conclusion:** This systematic literature search identified a surprisingly low number of studies examining the association between pin site infection and the specific host factors. Thus, this review most of all serves to demonstrate a gap of evidence about the correlation between host factors and risk of pin site infection, and further studies are warranted.

Keywords: *External fixation, host factors, pin site infection*

Introduction

External fixation is widely used for initial and final treatment of complex fractures as well as for limb lengthening and reconstruction of bone deformities including infections. Advantages of external fixation include fracture fixation without interfering with the fracture site or the concomitant soft-tissue zone of injury. Furthermore, external fixation allows for gradual deformity correction even in the skeletally immature patient. External fixation provides good and reliable results.[1,2] However, a major drawback is the risk of pin site infection occurring at the site where the external wires or pins penetrate the skin. In the literature, the incidence of pin site infection varies widely and depends on its classification and severity, and if expressed as the number of pin sites or the number of patients. A recent prospective study of 39 trauma, limb deformity, and bone infection patients treated with external fixation reports an infection rate of 30% of the included pin sites corresponding to 92.5% of the patients.[3] Even though the most pin site infections are superficial, this complication often results in patient pain and need for increased pin site care or antibiotic treatment. If the infection proceeds to deep infection, the treatment might fail due to loosing of fixation or the development of osteomyelitis.

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Utilizing a modified Delphi approach an international Pin Site Consensus Group has identified the topic of host factors affecting pin site infection to be one of the top 10 priorities in pin site management (personal communication). To prevent pin site infection, patient selection and optimization of modifiable host factors seem important to consider. Although previous reviews have provided recommendations for preventing pin site infection when using external fixation.[4,5] the literature is limited in regards to reporting correlations between pin site infections and patient host factors.[6] Therefore, we conducted a systematic literature search on the host factors affecting pin site infection.

Materials and Methods

This systematic literature search was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis Protocols (PRISMA) guidelines 2020.[7] The protocol was registered before data extraction in the International Register of Systematic Reviews, PROSPERO (ID: CRD42021273305). The intention was an etiological literature review, determining the association between specific host factors and the outcome pin site infection. A review of etiology is defined by Joanna Briggs Institute (JBI) as a review identifying and synthesizing the evidence of possible associations.[8] Data were extracted if feasible, however, no meta-analysis was performed, and no narrative synthesis of data is presented. The aim was to report the frequency of studies reporting specific host factors to be associated with pin site infection. The host factors to be assessed were (a) age, (b) smoking, (c) BMI, (d) any comorbidity, and (e) diabetes.

The search string was based on the Population, Intervention or Exposure of interest, Comparison, Outcomes (PICO) criteria. P: Patients treated with external fixation. I/E: Host factors associated with the development of pin site infection. C: Patients who did not develop pin site infection. O: Patients who developed pin site infection.

Eligibility criteria

Studies were included if they met the following criteria: Patients treated with external fixation, one or more patients who developed pin site infection, description of at least one host factor, and papers published in peer-reviewed journals only. Studies were excluded if they met the following exclusion criteria: Not written in English, German, Danish, Swedish, or Norwegian. Animal or cadaveric studies. Pin location at the cranium, face skeleton, spine, or thorax. Editorials or conference abstracts. The absence of numerical data on either the outcome (pin site infection) or the comparator group (no pin site infection). Absence of data on the specific host factors of interest (intervention/exposure).

Definition of pin site infection and outcome in search strategy

Several classification systems for pin site infections exist, but no international consensus/guideline is currently universally accepted. Terminology varies among the literature and standard terms that describe the content of our outcome is unique for every database. The logic grid [Table 1] shows how the search strategy was developed from the terminology.

Information sources

The literature search was executed in three electronic bibliographic databases on the 16th of August 2021, including Embase MEDLINE (1111 hits) and CINAHL (2066 hits) through Ovid and Cochrane Library CENTRAL (387 hits) at its own website. The search included all peer-reviewed publications in the language; English, German, Danish, Swedish, and Norwegian from the year 1980 to 2021. A total of 3564 titles were found. We did not search for gray literature on Google scholar, and we did not hand search references or contact any specific authors.

Search strategy

The literature search strategy was developed using terms related to external fixator constructs, pin site infection, and the host factors of interest. From the PICO elements, a logic grid with key concepts, keywords, and index terms was made, and from that framework, a building block search strategy was designed. The search string was built with the help from a librarian from Aalborg University Hospital, Denmark. To achieve a high recall/sensitivity rate, we implemented a broad search with a low-precision rate,[9] as advised in the Cochrane Handbook for Systematic Reviews of Interventions.[10] We used both Medical Subject Headings (MeSH) and free-text words, combined with Boolean operators and truncations when suitable. No search limitations were added and the exact search strategy in each of the three databases can be found in Appendix 1.

Selection process

All records were transferred to Endnote (Clarivate Analytics, Philadelphia, Pennsylvania, USA) and 302 duplicates were removed using the built-in software. A total of 3362 records were transferred for screening in the software Covidence (Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). A pilot of 10 studies was conducted initially. All four authors screened the first 10 records that came up by alphabetic filtering only from title and abstract. They were discussed on a meeting in terms of inclusion and exclusion criteria to ensure consensus for the further selection process. All authors agreed on those 10 records without conflicts. Following all remaining records were screened from title and abstract independently by two authors (SK, MF, JR, or MB). Each author allocated all records to one of three groups (accept, maybe, and reject)

Table 1: Logic grid of blocks with keywords and index terms

Population	Intervention (exposure)	Comparison	Outcome measures
Index term	Index term	No infection	Keywords
External fixator	"Smoking" (tobacco)	No complication	Pin site infection
Key words	Index term	No infection signs	Pin tract infection
"External frame"	"Diabetes mellitus"	No infection symptoms	Complication
"Orthopedic frame*"	Diabetic		Failure
"Orthopedic frame*"	BMI		Not used
"External device"	Index term		Postoperative
"Percutaneous rod"	"Body mass"		Postoperative
"Percutaneous pin"	"Body mass index"		
"Fixate"	"Overweight"		
"Wire"	"Adiposities"		
"Pin"	"Obesity" (weight) (height)		
"Rod"	Age		
"Nail"	All ages no search limitations (adult, child, skeletal mature pediatric, adolescent, paediatric)		
Pinsite, pin site, pin-site*			
Pintract, pin tract, pin-tract*	"Comorbidity"		
Keywords: Not used	"Health status"		
Correction	"General health"		
Transport			
Deformity correction temporary fixation			
Surgical wound			

BMI: Body mass index

based on the title and abstract. Records approved by two authors went into the full-text screening which was also done independently by two authors. The records labeled in the category "maybe" was discussed in a meeting by all four authors and the final decision of acceptance or rejection was agreed on. During the full-text screening a search for additional, supplementary, or appendix was done using the PDF word search tool searching for "Appen," "Addi," and "Suppl." The folder with unsure records was finally scored and solved by a third author, and in case of doubt, the senior author (SK) was consulted and eventually the entire author group. During the data extraction process, 6 studies more were excluded, 3 studies were excluded because numerical data were not extractable, and 3 studies were excluded because 100% of the patients had diabetes without a comparator group and no data of any of the other specific host factors of interest (intervention/exposure) was available.

Data collection

Data extraction was performed in collaboration between all authors, using a pre-designed excel spreadsheet. Discrepancies were reviewed, and disagreements were settled by discussion in the group or conferring with the senior author (SK). No authors were contacted in case of missing data but if additional material was available in online, it was looked up. Records were sought for the following variables, and the data items were noted in the data extraction spreadsheet tool: Title of the paper; Author; Journal; Publication Year; Study design; Number of patients included; Diagnosis/Reason for frame (e.g., Charcot, open tibia fracture); Location of frame (e.g., Femur/Tibia/Foot/Upper extremity); Number of patients with pin site infections; Number of patients without pin site infection; Pin site infection classification system used; Age; BMI; Smoking; Comorbidity; Diabetes; Conclusion.

Data synthesis

The outcomes of this systematic literature search were of qualitative nature because we aimed to review the literature for primary research data on pin site infections and the association to the specific host factors. No data meta-analysis was performed. Instead, we report for each of the host factors mentioned above, the number of studies reporting on a possible association with pin site infection in a tabular summary as presented in Tables 2-8.

Risk of bias in the studies

Following the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis, 2020[22] quality assessment of the included studies was done using JBI Critical Appraisal Tool. Since all studies were retrospective (cohort and case–control studies) the JBI critical appraisal checklists for case–control and cohort studies were used [Appendix 2]. The checklists consist of 10 and 11 questions, respectively, graded into four categories: Yes, No, Unclear, and Not applicable. All studies were assessed by two different

Table 2: Overview of study design, aim and risk bias assessment [Appendix 2] of the 11 included studies

Author	Study design	Aim of study	Publ. Year	Q 1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Agashe et al.	Retrospective cohort/case series	Evaluate surgical method	2013	√	√	√	√	√	√	√	√	√	0	√
Berven et al.	Retrospective cohort, multicentre	Compare ex fix vs. ORIF. Pin site infections reported in supplementary material	2018	√	√	√	√	√	√	√	√	√	√	√
Fedorak et al.	Retrospective cohort	Assess obesity as risk factor for increased complications	2015	√	√	√	√	?	√	√	√	√	√	√
Finkler et al.	Retrospective cohort	Asses the risk of pin site infection in this high-risk patient population	2015	?	√	√	?	X	√	√	?	√	0	?
Lyons et al.	Retrospective cohort	Validate the use of the ACS NSQIP	2021	√	√	?	?	?	√	?	√	√	?	√
Marsh et al.	Retrospective cohort	Analyse the radiographic and clinical results	1995	√	X	?	X	X	√	√	√	√	0	0
McDonald et al.	Retrospective cohort	Investigate superficial and deep infection	2017	√	√	√	√	√	√	√	√	√	√	√
Shakir et al.	Retrospective case-control study	Evaluation of infection rate and risk factors.	2018	0	0	√	√	√	√	X	√	X	?	
Tomic et al.	Retrospective cohort	Functional outcomes and patient satisfaction	2007	√	√	√	X	X	√	√	√	√	0	0
Wukich et al.	Retrospective case-control study	Complications to circular ring fixation in diabetic patients vs. non-diabetic patients.	2008	√	0	√	√	√	√	√	√	√	√	
Yikemu et al.	Retrospective case-control study	Evaluation of vacuum sealing drainage combined with Ilizarov. Focus on risk factors for postoperative pin infection	2019	0	0	√	√	√	?	√	√	√	√	

Scale: Green=Yes, Red=No, Yellow=Unclear, White=Not applicable, Grey=Only 10 questions for case-control studies

authors, and conflicts were sorted at a meeting between the two. The assessments were based on the primary aim of each study, with pin site infections and host factors as secondary outcomes if necessary.

Effect measures and statistics

Pin site infections and host factors were assessed as a binary outcome. Analyses were carried out using Stata® 16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC). When comparing different groups for pin site frequency, a risk of type I error below 0.05 was considered statistically significant.

Results

Study selection

A total of 3302 records were included for screening, of which 11 studies were included[11-21] in the review [Figure 1].

Study characteristics

The included studies were all designed retrospective [Table 2]. Three of the studies were case–control studies[18,20,21] The studies included in total n = 1445 patients of which n = 276 patients had pin site infection [Table 3]. All studies were published within the year from 1995 to 2021 [Table 2]. One study included had online available supplementary data that were used to extract data on risk factors of pin site infection.[12]

Risk of bias assessment

Only 2[2,17] out of the 11 included studies had the primary aim to investigate an association between host factors and pin site infection in external fixation [Table 2]. Results of the risk of bias assessment using the JBI Critical Appraisal Tool are presented in Table 2.

Table 3: Alphabetic tabular summery, an overview of extracted data from the 11 included studies

	Study population	Patient (*n*)	Pin location (*n*)	PI (*n*)	Smoking	Diabetes	BMI	Age	Comorbidity	Specifictaions on comorbidity
Agashe *et al*.[12]	Cerebral palsy, hips	16	Pelvis, femur	6				X	X	GMFCS grade
Berven *et al*.[13]	Prox tibia fractures	62	Tibia	40%	X		X	X	X	ASA score, ISS score
Fedorak *et al*.[14]	Paediatric orthopaedic conditions	208	Tibia, femur	74			X			
Finkler *et al*.[15]	Charcot deformity	283	Tibia, foot	59		X	X		X	Osteomyelitis, HbA1c level
Lyons *et al*.[16]	Charcot deformity	85	Tibia, foot	26		X			X	Diabets and CHF
Marsh *et al*.[17]	Complex tibia plateau fractures	21	Tibia	9				X		
McDonald *et al*.[18]	Pelvis fracture (no=52)	52	Pelvis	10	X		X	X	X	ASA score, ISS score
Shakir *et al*.[19]	Pelvis, acetabulum and femur fractures	556	Tibia, femur, calcaneus	5				X		
Tomić *et al*.[20]	Humeral shaft nonunion	28	Humerus	6				X		
Wukich *et al*.[21]	Foot ankle surgery	56	Mid-hind-foot and/or ankle	37		X				
Yikemu *et al*.[22]	Traumatic osteomyelitis	78	Tibia	19	X	X	X	X	X	Hypertension, alcoholism, COPD
Total (*n*)	Results for each host factor in Tables below	1445		276	Table 9	Table 8	Table 6	Table 5	Table 7	

X=Exact number of patients in each group (PI and no PI) was not available, but an estimated *P* value is available or mentioned in the study. PI: Pin site infection, GMFCS: Gross Motor Function Classification System, ASA: American Society of Anaesthesiology, ISS: Injury severity score, HbA1c: Haemoglobin A1C, CHF: Congestive heart failure, COPD: Chronic obstructive pulmonary disease, BMI: Body mass index

Table 4: Correlation between age and pin site infection

Study author	Age (PI)	Age (no PI)	*P*
Agashe *et al*.	15.8 (12-25)	20.2 (12-33)	0.32
Berven *et al*.	54.7 (48-62)	56.3 (52-61)	0.68
Marsh *et al*.	41.1	45.7	0.36
sssMcDonald *et al*.	40.8±17.6	48.5±17.3	0.23
Shakir *et al*.	48 (20-62)	43.9 (16-90)	>0.05
Tomic *et al*.	45	42.3	0.73
Yikemu *et al*.*	12 (63.16)	12 (20.34)	3.52

*Age was specified as ≥50 years (not estimated for the group <50 years). Mean±SD or median (range). SD: Standard deviation, PI: Pin site infection

Table 5: Mean Body mass index (kg/m^2) for groups with and without pin site infection (±standard deviation of body mass index)

Study	BMI (PI)	BMI (no PI)	*P*
Berven *et al*.	26.2	26.8	0.68
Fedorak *et al*.	See text	See text	See text
Finkler *et al*.	See text	See text	0.288
McDonald *et al*.	29.7±7.1	26.3±6.1	0.182
Yikemu *et al*.	22.5±1.82	22.97±1.88	0.396

PI: Pin site infection, BMI: Body mass index

Results of individual studies

A tabular summary of the included studies is provided in Table 3. Out of the 11 studies, a possible correlation between host factors and pin site infection was reported as follows: age: 7 studies [Table 4], BMI: 5 studies [Table 5], different comorbidities: 6 studies [Table 6], diabetes mellitus: 4 studies [Table 7], and smoking: 3 studies [Table 8].

Age

None of the five studies found that age was a significant risk factor for pin site infection [Table 4].

Body mass index

None of the five studies found that BMI was a significant risk factor for pin site infection [Table 5]. In the pediatric study by Fedorak *et al*.[13] differences were found for pin site infection between the three groups: normal weight (31.2% pin site infection), overweight (42.9% pin site infection), and obese (38.3% pin site infection). However, these differences were not statistically significant (P = 0.46). Finkler *et al*.[14] found that patients with pin site infection had a mean BMI of 35 kg/m (2) compared with patients without infection with a mean BMI of 38 kg/m (2). There

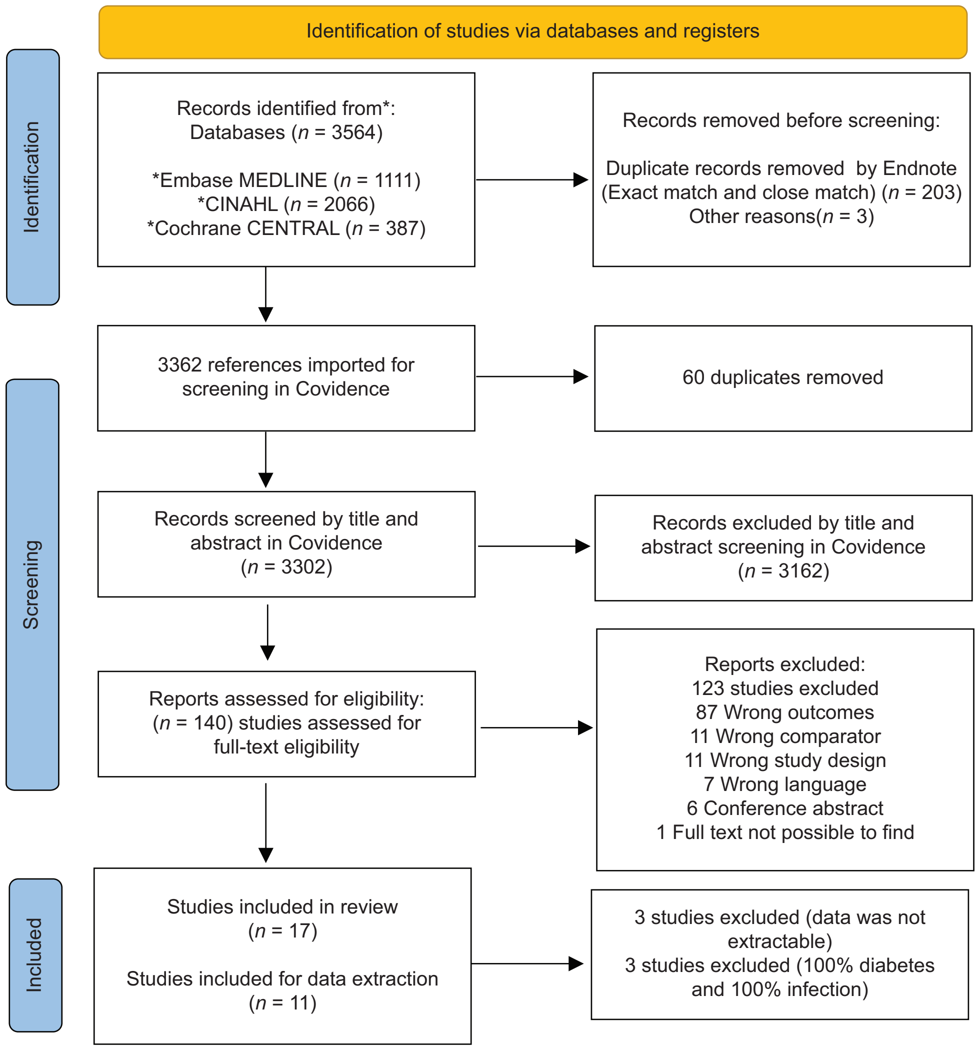

Figure 1*:* **PRISMA flow diagram for systematic reviews searches of databases and registrars only**[7]

was not a statistically significant difference in BMI between the two groups ($P = 0.3$).

Comorbidities

McDonald *et al*.[17] found a significant association between lower American Society of Anesthesiology (ASA) score and higher risk of pin site infection. No significant correlation to preoperative osteomyelitis, Gross Motor Function Classification System (GMCFS) grade, injury severity score, hypertension, and alcoholism chronic obstructive pulmonary disease was found in the included studies.

Diabetes mellitus

None of the studies found that diabetes was a statistically significant risk factor for pin site infection. Wukich *et al*.[20] demonstrated a higher risk of minor wire complications in the diabetes group ($P = 0.01$) but "wire complications" was not defined as pin site infection alone. Finkler *et al*.[14] found a statistically significant increased rate of pin site infection in patients with higher hemoglobin A1C levels ($P < 0.05$). Lyons *et al*.[15] investigated a patient population treated for Charcot foot deformity and found in these diabetic patients a higher rate of pin site infection for patients with congestive heart failure.

Smoking

None of the studies included found that smoking was a significant risk factor for pin site infection.

Discussion

To the best of our knowledge, this is the first review based on a systematic literature search examining the association between host factors and pin site infections. A total of 11 studies met the inclusion criteria making it possible to extract data regarding pin site infection and the predefined specific host factors: age, BMI, smoking, and comorbidity including diabetes. The majority of included studies did not demonstrate a significant association between pin site infections and the examined host factors. Significant associations between pin site infection were found for the following host factors: (a) increased HbA1C level in diabetic patients,[14] (b) congestive heart failure in diabetic

Table 6: Comorbidity score or absolute number/frequency of comorbidity for groups with and without pin site infection

Study	Comorbidity (PI)	Comorbidity (no PI)	*P*	Comorbidity specified
Agashe *et al*. (%)	5 (83)	3 (60)	0.4	GMFCS grade
Berven *et al*.	1.78	1.88	0.9	ASA score
	9.0 (range: 9-27)	9.0 (range: 9-18)	0.88	ISS score
Finkler *et al*. (%)	28 (25.6)	31 (17.8)	0.12	Osteomyelitis
	9.4	8.3	<0.05	HbA1c level
Lyons *et al*.	Est. from ROC curve	Est. from ROC curve	0.01	Diabetes and CHF
McDonald *et al*.	2.0±067	2.7±0.92	0.01	ASA score
	35.2±14.2	35.9±13.2	0.17	ISS score
Yikemu *et al*. (%)	8 (42.11)	24 (40.68)	0.91	Hypertension
	4 (21.05)	9 (15.25)	0.35	Alcoholism
	3 (15.79)	5 (8.47)	0.36	COPD

PI: Pin site infection, GMFCS: Gross Motor Function Classification System, ASA: American Society of Anaesthesiology, ISS: Injury severity score, HbA1c: Haemoglobin A1C, CHF: Congestive heart failure, COPD: Chronic obstructive pulmonary disease, ROC: Receiver operator characteristic

Table 7: Absolute number/frequency of diabetes for groups with and without pin site infection

Study	Diabetes (PI)	Diabetes (no PI)	*P*	Conclusion
Finkler *et al*.	NA	NA	NA	There was a trend for an increased rate of pin site infection in patients with higher HbA1c levels (*P*<0.05)
Lyons *et al*.	NA	NA	NA	A higher rate of pin site infection was found in diabetic patients with CHF compared with diabetic patients without CHF
Wukich *et al*.	NA	NA	NA	Higher risk of minor wire complications in the diabetes group (*P*=0.01). "Wire complications" was not defined as pin site infection alone
Yikemu *et al*. (%)	7 (3.68)	18 (30.51)	0.607	

NA: Not available, PI: Pin site infection, HbA1c: Haemoglobin A1C, CHF: Congestive heart failure

Table 8: Absolute number/frequency of smoking for groups with and without pin site infection

Study	Smoking (PI)	Smoking (no PI)	*P*
Berven *et al*. (%)	34.8	46.2	0.39
McDonald *et al*. (%)	30	31.80	0.63
Yikemu *et al*. (%)	13 (68.42)	46 (77.79)	0.40

PI: Pin site infection

patients (15), and (c) lower ASA score, representative of lower comorbidity.[12]

Pin site infection is a frequent complication and was in some of the studies found to be as high as 100%.[23-25] Therefore, it is surprising that the literature is scarce of studies examining host factors and their association with pin site infection. The risk of bias is generally high for all included studies as they all are retrospective studies with small numbers of patients and infected pin sites. However, the risk assessment demonstrated that most of the included studies followed best practice for retrospective studies. Only two studies[18,21] had the primary aim of investigating the correlation between host risk factors and pin site infection. As no standardized assessment tool to clinically evaluate or report pin site infection exists, there is a potential risk of bias in this work. No studies were excluded from the systematic literature search based on their methodological quality or bias potential. None of the included studies used a clinical pin site infection grading system when reporting on pin site infection. The inconsistency on how to report on pin site infections and how to define a pin site is a major clinical challenge. Wukich *et al*.[20] found a higher risk of minor complications in diabetic patients and defined a minor complication as an event in which a change was not required in the treatment plan. These included fine wire irritation, drainage, pin loosening not resulting in return to the operating room, minor skin traction/necrosis, or superficial infections that resolved with topical or oral antibiotics. None of the four studies investigating the association to diabetes found that diabetes was an isolated risk factor for pin site infection. However, Finkler *et al*.[14] found a statistically significant increased rate of pin site infection in patients with higher hemoglobin A1C levels ($P < 0.05$). Lyons *et al*.[15] investigated a patient population treated for Charcot foot deformity and found in these diabetic patients, a higher rate of pin site infection for patients with congestive heart failure. This might indicate that dysregulated diabetic patients should be preoperative optimized before treatment with an external frame. Further, the evidence on the association with comorbidity can be discussed. McDonald *et al*. found a significant association between lower ASA scores and the risk of pin site infection, but after logistic regression for possible confounding variables, the correlation was no longer significant.

The strength of this study is that the results are presented as tabular summaries of the extracted numeric data, the literature search strategy was constructed evidence-based, and the eligibility process is well documented. This approach introduces no reporting bias. Concerning limitations introduced by our eligibility criteria, we have included only studies reporting on the specific number of patients who developed pin site infection and the association to the specific host factors of interest. Host factor data are in most studies reported as an appendix or as a figure presenting the demographics because the primary aim of the studies was not to examine for a correlation between pin site infection and host factors. We only included papers from peer-reviewed journals which might be a limitation; however, it might also increase the quality of the included studies.

A systematic literature search is always limited by the design of the search strategy and the applied eligibility criteria. We used the methodological systematic approach suggested by Cochrane by constructing a block search strategy based on the PICO criteria.

Throughout the process of producing this manuscript, two RCT studies comparing different pin care regimes with the risk of pin site infection were suggested to be included. The studies were not revealed by this systematic review block search strategy because neither the title nor the abstract included words or mesh terms related to the intervention/exposure block. The first study by Egol *et al*.[6] prospectively randomized 120 wrists with pins to receive two different pin care regimes. In this study, the age of the patient was found to have a significant (P = 0.04) increased risk of pin site complications with an average age of 51 years (no complications) versus 64 years (complications). No validated pin site infection classification system was applied; instead, erythema, cellulitis, drainage, pin loosening, and radiological loosening were assessed. Moderate correlations between cellulitis around the pin and both ASA score (P = 0.03) and number of comorbidities (P = 0.02) were found. The second study by Fergusson *et al*.[26] prospectively enrolled 116 patients with external frames on the lower extremity comparing traditional versus emollient pin care regimes. Forty-eight patients (41%) developed a pin site infection, assessed by the "Good, Bad Ugly approach"[27] and no difference was found between the two regimes. Furthermore, no statistically significant association between age, BMI, sex, ethnicity, smoking and comorbidity and pin site infection was found.

The host factors to be examined in this systematic literature search were chosen based on the clinical experience from the authors. Thus, the authors thought that the host factors age, comorbidity, and in particular, the modifiable host factors: smoking and diabetes might increase the risk of pin site infection. In addition, it was expected that these host factors had a sufficiently high prevalence in the studies to allow for association assessments. The current literature demonstrates a gap in evidence that the host factors smoking, diabetes, increased age, and increased BMI are associated with increased risk of pin site infection. However, this lack of evidence should be interpreted with caution due to the small sample sizes and the high risk of bias in the retrospective studies. Thus, this review most of all serves to demonstrate a gap in evidence, and further studies are warranted. Future studies should be designed to prospectively examine associations between host factors and pin site infection and include a sufficient number of patients to make a sound conclusion about the absence of risk factors. Furthermore, it is of paramount importance that a universally accepted definition of pin site infection is developed and applied in all future studies. A stringent definition of pin site infection is needed to allow for accurate estimates of pin site infection and to allow for comparison between different studies.

Conclusion

This systematic literature search identified a surprisingly low number of studies examining for risk of pin site infection and host factors. The included studies did not demonstrate a significant association between pin site infections and the examined host factors: age, BMI, smoking, and diabetes. Individual retrospective studies reported a significant association between pin site infection and increased HbA1C level in diabetic patients; congestive heart failure in diabetic patients; and lower ASA score, representative of lower comorbidity.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1: Documentation of literature search string

Number	Embase search conducted 16.08.21	Results
#1	external fixator'/exp AND 'external fixator':ab, ti	2853
#2	(external NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti	12,379
#3	(bone NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti	5070
#4	(fracture* NEAR/3 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti	17,477
#5	((orthopaedic OR orthopedic) NEAR/2 (wire* OR pin* OR rod* OR nail*)):ab, ti	165
#6	(percutaneous NEAR/2 pin*):ab, ti	1099
#7	steinmann pin*':ab, ti OR 'kirschner wire*':ab, ti	4013
#8	steinmann pin*':ab, ti OR 'kirschner wire':ab, ti	2496
#9	skeleton traction':ab, ti OR 'skeleton traction'/exp	1029
#10	external frame':ab, ti OR 'orthopedic frame*':ab, ti OR 'external device':ab, ti	673
#11	pinsite: ab, ti OR 'pin site':ab, ti OR 'pins site':ab, ti OR 'pins tract':ab, ti OR pintract: ab, ti OR 'pin tract':ab, ti	1395
#12	('external fixator'/exp AND 'external fixator':ab, ti) OR (external NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR (bone NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR (fracture* NEAR/3 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR ((orthopaedic OR orthopedic) NEAR/2 (wire* OR pin* OR rod* OR nail*)):ab, ti OR (percutaneous NEAR/2 pin*):ab, ti OR ('steinmann pin*':ab, ti OR 'kirschner wire*':ab, ti) OR ('steinmann pin*':ab, ti OR 'kirschner wire':ab, ti) OR ('skeleton traction':ab, ti OR 'skeleton traction'/exp) OR ('external frame':ab, ti OR 'orthopedic frame*':ab, ti OR 'external device':ab, ti) OR (pinsite: ab, ti OR 'pin site':ab, ti OR 'pins site':ab, ti OR 'pins tract':ab, ti OR pintract: ab, ti OR 'pin tract':ab, ti)	37,826
#13	smoking: ab, ti OR 'smoking'/exp OR 'diabetes mellitus':ab, ti OR 'diabetes mellitus'/exp OR 'body mass':ab, ti OR 'body mass'/exp OR comorbidity: ab, ti OR 'comorbidity'/exp OR obesity: ab, ti OR overweight: ab, ti OR adiposity: ab, ti OR 'obesity'/exp OR 'health status':ab, ti OR 'general health':ab, ti OR 'health status'/exp OR 'general health'/exp	2,727,450
#14	inflammation'/mj OR inflammation: ab, ti	728,687
#15	infection'/mj OR infection: ab, ti	1,566,076
#16	pin site infection'/mj OR 'pin site infection':ab, ti	219
#17	complication: ab, ti OR 'complication'/exp OR failure: ab, ti OR 'failure'/exp	2,567,432
#18	('inflammation'/mj OR inflammation: ab, ti) OR ('infection'/mj OR infection: ab, ti) OR ('pin site infection'/mj OR 'pin site infection':ab, ti) OR (complication: ab, ti OR 'complication'/exp OR failure: ab, ti OR 'failure'/exp)	4,451,179
#19	(('external fixator'/exp AND 'external fixator':ab, ti) OR (external NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR (bone NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR (fracture* NEAR/3 (fixat* OR wire* OR pin* OR rod* OR nail*)):ab, ti OR ((orthopaedic OR orthopedic) NEAR/2 (wire* OR pin* OR rod* OR nail*)):ab, ti OR (percutaneous NEAR/2 pin*):ab, ti OR ('steinmann pin*':ab, ti OR 'kirschner wire*':ab, ti) OR ('steinmann pin*':ab, ti OR 'kirschner wire':ab, ti) OR ('skeleton traction':ab, ti OR 'skeleton traction'/exp) OR ('external frame':ab, ti OR 'orthopedic frame*':ab, ti OR 'external device':ab, ti) OR (pinsite: ab, ti OR 'pin site':ab, ti OR 'pins site':ab, ti OR 'pins tract':ab, ti OR pintract: ab, ti OR 'pin tract':ab, ti)) AND (smoking: ab, ti OR 'smoking'/exp OR 'diabetes mellitus':ab, ti OR 'diabetes mellitus'/exp OR 'body mass':ab, ti OR 'body mass'/exp OR comorbidity: ab, ti OR 'comorbidity'/exp OR obesity: ab, ti OR overweight: ab, ti OR adiposity: ab, ti OR 'obesity'/exp OR 'health status':ab, ti OR 'general health':ab, ti OR 'health status'/exp OR 'general health'/exp) AND (('inflammation'/mj OR inflammation: ab, ti) OR ('infection'/mj OR infection: ab, ti) OR ('pin site infection'/mj OR 'pin site infection':ab, ti) OR (complication: ab, ti OR 'complication'/exp OR failure: ab, ti OR 'failure'/exp))	1112
Number	**CINAHL search conducted 16.08.21**	**Results**
S1	MH external fixators OR TI external fixator* OR AB external fixator*	1795
S2	TI (external N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails) OR AB (external N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails)	45,345
S3	TI (bone N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails) OR AB (bone N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails)	44,916
S4	TI (fracture N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails) OR AB (fracture N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails)	44,915
S5	TI (orthopedic or orthopaedic) OR AB (orthopedic or orthopaedic) OR TI (orthopedics or orthopaedics) OR AB (orthopedics or orthopaedics)	34,908
S6	TI (S5 N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails) OR AB (S5 N2 fixator OR fixation OR wire OR pin OR pins OR rod OR rods OR nail OR nails)	44,907
S7	TI percutaneous n2 pin OR pins OR AB percutaneous n2 pin OR pins	544
S8	TI "steinmann pin OR pins" OR AB "steinmann pin OR pins"	82
S9	TI "kirschner wire" OR AB "kirschner wire"	426

Contd...

Appendix 1: Contd...

Number	Embase search conducted 16.08.21	Results
S10	TI traction OR AB traction OR MH traction	4834
S11	TI skeletal traction* OR AB skeletal traction*	139
S12	TI ("external frame" OR "orthopedic frame" OR "external device") OR AB ("external frame" OR "orthopedic frame*" OR "external device*")	180
S13	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12	83,714
S14	TI ("pin site' OR pinsite' OR pin-site' OR pins site') OR AB ("pin site' OR pinsite' OR pin-site' OR "pins site")	96
S15	TI ("pins tract' OR pintract' OR pin-tract' OR "pins tract" OR pintract OR "pin-tract") OR AB (pin site' OR pinsite' OR "pin-site" OR pins site' OR pintract OR "pin-tract")	727
S16	TI (complication* OR failure) OR AB (complication* OR failure)	357,182
S17	S14 OR S15 OR S16	357,255
S18	MH "diabetes mellitus" OR TI "diabetes mellitus" OR AB "Diabetes Mellitus"	106,882
S19	MH smoking OR TI smoking OR AB smoking	106,991
S20	MH "body mass index" OR TI "body mass index" OR AB "body mass index"	121,551
S21	TI overweight OR AB overweight	33,672
S22	TI adiposity OR AB adiposity	8628
S23	MH obesity OR TI obesity OR AB obesity	128,039
S24	MH "health status" OR TI "health status" OR AB "health status"	73,338
S25	TI 'general health' OR AB 'general health'	23,925
S26	MH comorbidity OR TI comorbidit* OR AB comorbidit*	99,682
S27	S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26	545,767
S28	S24 OR S25	92,475
S29	S13 AND S17 AND S28	146
S30	S13 AND S17 AND S26	795
S31	S13 AND S17 AND S19	246
S32	S13 AND S17 AND S18	235
S33	S20 OR S21 OR S22 OR S23	214,909
S34	S13 AND S17 AND S33	643
S35	S13 AND S17 AND S27	1681
S36	S13 OR S14 OR S15	83,715
S37	MH infection OR TI infection OR AB infection	246,645
S38	MH inflammation OR TI inflammation OR AB inflammation	88,982
S39	S16 OR S37 OR S38	638,911
S40	S27 AND S36 AND S39	2066

#1	MeSH descriptor: [External Fixators] explode all trees		MeSH ▾	1049
#2	MeSH descriptor: [Bone and Bones] explode all trees		MeSH ▾	13381
#3	(external fixators):ti,ab,kw	S ▾	Limits	202
#4	(bone and bones):ti,ab,kw	S ▾	Limits	2628
#5	MeSH descriptor: [Bone Screws] explode all trees		MeSH ▾	828
#6	MeSH descriptor: [Bone Wires] explode all trees		MeSH ▾	179
#7	MeSH descriptor: [Bone Nails] explode all trees		MeSH ▾	442
#8	(external NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)):ti,ab,kw	S ▾	Limits	688
#9	bone NEAR/2 (fixat* OR wire* OR pin* OR rod* OR nail*)		Limits	1015
#10	(fracture* NEAR/3 (fixat* OR wire* OR pin* OR rod* OR nail*)):ti,ab,kw	S ▾	Limits	3145
#11	(((orthopaedic OR orthopedic) NEAR/2 (wire* OR pin* OR rod* OR nail*))):ti,ab,kw	S ▾	Limits	11
#12	((percutaneous NEAR/2 pin*)):ti,ab,kw	S ▾	Limits	124
#13	(steinmann NEXT pin*):ti,ab,kw	S ▾	Limits	6
#14	(kirschner NEXT wire):ti,ab,kw	S ▾	Limits	193
#15	MeSH descriptor: [Traction] explode all trees		MeSH ▾	211
#16	("skeleton traction"):ti,ab,kw	S ▾	Limits	26
#17	('external frame' OR 'orthopedic frame*' OR 'external device'):ti,ab,kw	S ▾	Limits	1422
#18	("pin site" OR pinsite OR "pin-site" OR "pins site" OR "pins tract" OR "pin tract" OR pintract OR pin-tract):ti,ab,kw	S ▾	Limits	114
#19	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10		Limits	18118
#20	#11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19		Limits	19672
#21	(#19 OR #20)		Limits	19672
#22	MeSH descriptor: [Smoke] in all MeSH products		MeSH ▾	415
#23	(smoking):ti,ab,kw	S ▾	Limits	33414
#24	MeSH descriptor: [Diabetes Mellitus] explode all trees		MeSH ▾	32988
#25	(diabetes mellitus):ti,ab,kw	S ▾	Limits	68200
#26	MeSH descriptor: [Body Mass Index] this term only		MeSH ▾	10459
#27	(body mass index):ti,ab,kw	S ▾	Limits	44398
#28	MeSH descriptor: [Overweight] explode all trees		MeSH ▾	17455
#29	(overweight):ti,ab,kw	S ▾	Limits	17932
#30	MeSH descriptor: [Adiposity] explode all trees		MeSH ▾	782
#31	(adiposity):ti,ab,kw	S ▾	Limits	2842
#32	MeSH descriptor: [Obesity] explode all trees		MeSH ▾	14700
#33	(obesity):ti,ab,kw	S ▾	Limits	39670
#34	MeSH descriptor: [Health Status] explode all trees		MeSH ▾	31780
#35	(health status):ti,ab,kw	S ▾	Limits	40880
#36	(general health):ti,ab,kw	S ▾	Limits	31786
#37	MeSH descriptor: [Comorbidity] explode all trees		MeSH ▾	3665
#38	(Comorbidity):ti,ab,kw	S ▾	Limits	15006
#39	#22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31		Limits	152447
#40	#32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39		Limits	246400
#41	MeSH descriptor: [Inflammation] explode all trees		MeSH ▾	11571
#42	("inflammation"):ti,ab,kw	S ▾	Limits	42994
#43	MeSH descriptor: [Infections] explode all trees		MeSH ▾	71496
#44	(infection):ti,ab,kw	S ▾	Limits	92957
#45	('pin site infection'):ti,ab,kw	S ▾	Limits	70
#46	#41 OR #42 OR #43 OR # 45 OR #45		Limits	238718
#47	#21 AND #40 AND #46		Limits	387

Appendix 2: JBI critical appraisal checklist, cohort and case-control studies

JBI critical appraisal checklist for cohort studies (Scale: Yes/no/unclear/not applicable)

Q1. Were the two groups similar and recruited from the same population?

Q2. Were the exposures measured similarly to assign people to both exposed and unexposed groups?

Q3. Was the exposure measured in a valid and reliable way?

Q4. Were confounding factors identified?

Q5. Were strategies to deal with confounding factors stated?

Q6. Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?

Q7. Were the outcomes measured in a valid and reliable way?

Q8. Was the follow up time reported and sufficient to be long enough for outcomes to occur?

Q9. Was follow up complete, and if not, were the reasons to loss to follow up described and explored?

Q10. Were strategies to address incomplete follow up utilized?

Q11. Was appropriate statistical analysis used?

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JBI critical appraisal checklist for case control studies (Scale: Yes/no/unclear/not applicable)

Q1. Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?

Q2. Were cases and controls matched appropriately?

Q3. Were the same criteria used for identification of cases and controls?

Q4. Was exposure measured in a standard, valid and reliable way?

Q5. Was exposure measured in the same way for cases and controls?

Q6. Were confounding factors identified?

Q7. Were strategies to deal with confounding factors stated?

Q8. Were outcomes assessed in a standard, valid and reliable way for cases and controls?

Q9. Was the exposure period of interest long enough to be meaningful?

Q10. Was appropriate statistical analysis used?

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JBI: Joanna Briggs institute