REVIEW ARTICLE

Pin-site Infection: A Systematic Review of Prevention Strategies

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Abstract

Introduction: Circular frame fixation remains a key tool in the armamentarium of the limb reconstruction surgeon. One of the key drawbacks is the onset of pin-site infection (PSI). As a result of limited evidence and consensus of PSI prevention, a wide variation in practice remains.

Aim: The principal aim of this review is to synthesise primary research concerning all aspects of treatment regarded as relevant to PSI in frame constructs.

Materials and methods: Comparative studies until week 26, 2021, were included in the trial. Studies were included that concerned patients undergoing management of a musculoskeletal condition in which pin-site care is necessary for over 4 weeks.

Results: Eighteen studies over a 13-year period were captured using the search strategy. Sulphadiazine and hydrogen peroxide cleansing was found to reduce PSI, with the use of low-energy fine wires and hydroxyapatite (HA)-coated pins also associated with lower infection rate. The remainder of studies found no significant improvement across interventions.

Conclusion: There is no superiority between weekly and daily care. Low-energy pin-insertion technique had lower rates of infection. Sulphadiazine has positive results as a pin-care solution, but more research is necessary to determine the most effective care regime. Current literature is limited by absence of established definitions and by a lack of studies addressing all aspects of care relevant to PSI.

Keywords: Classification, Diagnosis, External fixation, Management, Pin-site infection, Prevention, Systematic review.

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Introduction

The biological benefits of frame fixation are well documented; however, a key drawback to the use of percutaneous fixation is the incidence of PSI.[1] Pin-site infection is a common sequelae of external fixation with estimated rates between 9 and 100%.[2–5] The large disparity of reported rates of PSI is thought to be due to difficulties concerning its classification.[1] Various scoring systems have been formulated relying on a wide variety of criteria, making it difficult to compare and contrast cases of PSI.[1] Current evidence describing its pathophysiology is also contradictory with various theories having been proposed.[2] The common denominator amongst these studies is the pathological and progressive inflammation in the presence of microbes. This is often driven by an abnormal microenvironment (typically micromotion), which reduces the ability of the host immune system to resist excessive bacterial proliferation.[3] Mitigation of PSI is crucial to prevention of its progress, the natural history of which is progression, bone lysis, loosening and mechanical failure of the construct causing more micromotion and PSI.[4]

With such high incidence of PSI, its onset is less of an adverse event, and more of an expected aspect of percutaneous treatment modalities. It is therefore our duty as care providers to take steps to minimise infection, appropriately diagnose and rapidly treat PSIs when they develop. There is much in the literature, both historic and recent, regarding PSI with percutaneous techniques; however, the majority of this research relates to temporary fixation for elective and trauma surgery. In contrast, there are limited primary data on the management of PSI for prolonged treatment strategies in which the solution is not simply to remove the offending wire. In addition, until recently, prevention strategies and management have been based upon individual and institutional observation combined with basic science research. Consequently, any data acquired have been challenging to generalise to a wider population. This is likely due to the variability of factors involved in aetiology of PSI, as well as in the mainstay of its management across different healthboards.[5] Therefore, it is necessary to review latest evidence concerning its prevention, diagnosis and management strategies, as well as the validity of current classification systems.

The aim of this review is to systematically interrogate the literature for primary research data on the prevention, diagnosis and management strategies used in PSI.

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Materials and Methods

Protocol and Registration

This systematic review was undertaken in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) guideline[6] and the Cochrane Handbook for Systematic Reviews of Interventions.[7] The review protocol was registered on the International Prospective Register of Systematic Reviews database (CRD42021265218).

Eligibility Criteria

Eligibility criteria were considered with respect to the population, intervention, comparator and outcome (PICO) framework, interrogating the reported populations of patients undergoing definitive management of any musculoskeletal condition in which prolonged (>4 weeks) of pin-site care is required. Included were clinical trials investigating primarily pin-site care for fine wire and half-pin constructs, coated and uncoated pins, Ilizarov, hexapod, monolateral and hybrid constructs. Excluded were studies evaluating temporising external fixators and external fixators of the hand and wrist.

Search Strategy

Eligible studies were used to establish a scientific basis for prevention of PSI (pin-site dressings, regimes and cleansing solutions) and impact of surgical decision (insertion technique, hardware choice). To represent a body of modern literature, we considered any publication from the inception of queried databases, through to the search date (week 26, 2021). Given the known limited body of comparative studies, all comparative studies (randomised, quasi-randomised, nonrandomised and retrospective) were included in the synthesis.

A comprehensive search strategy, outlined in Table 1, was executed on the 'MEDLINE(R) (1946 to June 14, 2021), EMBASE (1980–2021 week 26) and Cochrane Central Register of Controlled Trials' databases. A snowballing exercise was undertaken to identify additional studies via references and conference abstracts.

Data Collection

DWS and ADI extracted data using a prepopulated data collection tool using the following domains: study characteristics, interventions, preventative measures, outcome measures and results.

Results

Following deduplication, the search strategy returned 3,212 articles. Following removal of ineligible articles and incorporation of additional records, 18 manuscripts were included in this systematic review (Flowchart 1). The studies were from 13 countries in 6 continents (Table 2).

Chan[8] compared iodophor dressings with saline dressings in patients undergoing distraction osteogenesis using the Ilizarov method and concluded no difference after 6 months of follow-up with a per-PSI rate of 19% and 17%, respectively.

Yuenyongviwat[9] reviewed a sulphadiazine dressing against a dry dressing in patients undergoing definitive fixation of their open fractures using external fixation. Only 15 patients were randomised to each group and found no difference with a per-patient infection rate of 47% and 40%, respectively.

Table 1: Search strategy

1	frame.mp
2	lengthening.mp
3	Ilizarov.mp
4	hexapod.mp
5	fixat.mp
6	1 or 2 or 3 or 4 or 5
7	infect.mp
8	loos.mp
9	reaction.mp
10	inflamm.mp
11	7 or 8 or 9 or 10
12	6 and 11
13	Limit 12 to English language
14	Limit 13 to (clinical trial or RCT or controlled clinical trial)
15	Limit 14 to yr='2001–current'
16	Remove duplicates from 15

RCT, randomised controlled trial

Flowchart 1: PRISMA flow diagram

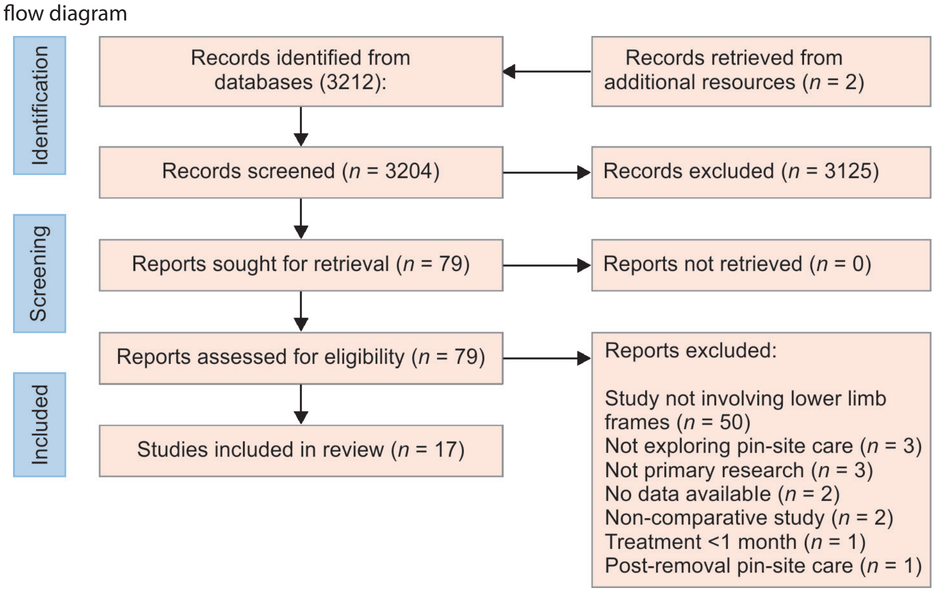

Table 2: Study characteristics

Authors	*Year*	*Location*	*Study type*	*Trial summary*	*Participants*	*Follow-up*
Chan[8]	2009	Malaysia	RCT	Iodophor vs saline dressings	• Distraction osteogenesis • Half pins and fine wires	6 months
Yuenyongviwat[9]	2009	Thailand	RCT	Sulphadiazine vs dry dressing	• Open tibial fractures • External fixator half pins	Until union
Ogbemudia[10]	2010	Benin, Nigeria	Case–control	Pin-site dressings. Sulphadiazine and chlorhexidine vs chlorhexidine alone	• 76 patients aged 5–75 • 37 half-pin and fine-wire constructs	Not declared
Lee[11]	2012	Malaysia	RCT	Plain gauze vs gauze impregnated with polyhexamethylene biguanide	• 38 patients (all ages) elective deformity circular frames • 40 limbs • 483 interfaces	12 weeks
Henry[12]	1996	London, UK	RCT	Pin-site care solution; control; none Gr1; 0.9% NaCl Gr2; 70% ETOH	• 30 adolescents (11–18) all circular fix	Frame removal 150 days (range 56–244)
W-Dahl[13]	2003	Sweden	RCT	• Daily vs weekly pin-site care	• Osteotomies for OA • Monolateral fixator	Mean 100 days
Patterson[14]	2005	Multicentre, USA	RCT	• Comparison of pin-care regime techniques • Cleansing solutions; hydrogen peroxide, saline, antibacterial soap • Dressings; Gauze/sponge, 3% bismuth tribromophenate and petroleum gauze	• 92 patients • Half pins and fine wires • Monolateral and circular fixation	24 months
Cavusoglu[15]	2009	Turkey	RCT	Cleaning—no solution vs povidone iodine	• 39 adult patients, trauma tibia Ilizarov frames	Frame removal
Camathias[16]	2012	Solomon Islands	RCT	Daily pin-site care vs no care	• (56 patients, 16 female, age 4–68 years, mean 24 years, in total 204 pins) all monolateral Ex-Fix >2/52	Frame removal mean 55 days (16–158)
Camilo[17]	2015	Brazil	RCT	• Pin-site care solution; NaCl vs povidone	• 30 patients (31-years-old, 14–59) all circular fix	Frame removal time; mean 273 days (95–726)
Subramanyam[18]	2019	India	RCT	Pin-site care solution: • Control; nil • Gr1; Povidone iodine • Gr2; Silver sulphadiazine • Gr3; Chlorhexidine • Secondary subdivision to daily or weekly care	• 114 patients (33.7, 15.6) all circular fix • C; 30 • Gr1; 27 • Gr2; 27 • Gr3; 30	Frame removal
Jalon[19]	2020	Cantabria, Spain	RCT	Comparison between chlorhexidine-alcohol solution and povidone-iodine solution for pin site	• 128 patients • 568 pins • Patients who underwent placement of an external fixator	Not declared
Ferguson[20]	2021	Multicentre, England, UK	RCT	Comparison between alcoholic chlorhexidine and emollient skin preparation	• 116 patients • Patients with tibial fractures treated with a circular frame	Not declared
Pommer[21]	2002	Germany	RCT	Hydroxyapatite vs uncoated half pins	• Monolateral fixator distraction osteogenesis	Minimum 12 weeks

(Contd...)

Table 2: *(Contd...)*

Authors	*Year*	*Location*	*Study type*	*Trial summary*	*Participants*	*Follow-up*
Piza[22]	2004	Barcelona, Spain	Quasi-randomised controlled trial	Uncoated conical half pins vs HA-coated half pins	• Children undergoing lengthening for skeletal dysplasia Tibial, femoral and humeral	530 ± 167 days
Davies[23]	2004	Liverpool, England	Nonrandomised comparative	Comparison of pin-insertion techniques	• External fixation for fracture and reconstruction Wires and half-pins	Not declared
Coester[24]	2006	Iowa, USA	RCT	SC half pins vs uncoated stainless steel	• 19 patients • Tibial monolateral fixators following trauma	Mean 16.7 weeks (range 8–31)
W-Dahl[25]	2008	Sweden	RCT	Conical vs self-drilling tapping half pins	• Osteotomies for OA • Monolateral fixator	Mean 98.5 days

RCT, randomised controlled trial

Ogbemudia[10] explored the addition of sulphadiazine to chlorhexidine dressings across a combination of half pin and fine-wire devices in adults and children undergoing external fixation for any cause (except in the presence of deep infection or ischaemia) and found a lower per-patient infection rate with the addition of sulphadiazine (8%) vs chlorhexidine alone (23.7%).

Lee[11] randomised 40 limbs into polyhexamethylene biguanide (PHMB) vs plain gauze dressings for a combination of indications (including infection) and across a range of bones. The results are presented as a product of PSIs across a multitude of observational timepoint (1,932 observations), and the authors attribute the addition of PHMB to pin-site dressings to reduce the infection rate with a relative risk of 0.22.

Henry[12] explored ethanol vs saline vs nothing as a pin cleansing solution in adolescents. Cleansing was carried out daily by a nurse, family or patient. No statistical analysis is presented, but the rate of 25% PSIs occurred with saline, compared to 17.5% with alcohol and 7.5% no solution.

W-Dahl[13] also compared the frequency of dressings in 50 patients randomised to weekly pin-site care or daily pin-site care for patients undergoing tibial osteotomies using a monolateral external fixator. Pins were cleaned with saline, crusts removed and absorbent dressings applied. After a mean of 100 days, there was 18% per-pin infection rate with weekly dressing and 13% in daily dressings, a difference which is not statistically significant.

Patterson[14] reported on 92 patients with half pins and fine wires on monolateral and circular fixators from two centres in the USA over 2 years. They explored multiple pin care regimes and solutions and concluded that only the combination of hydrogen peroxide cleansing and Xeroform dressings was superior to other combinations of saline, soap or gauze dressings.

Cavusoglu[15] investigated iodine cleansing compared to soap (following the first 2 weeks of iodine cleansing) in participants with fine wire external fixators to the lower leg only. From 611 pin sites, they found a per-pin infection rate of 43.6% in the iodine cohort and 50.7% in the soap cohort with no statistical difference between the two.

Camathias[16] randomised daily pin-site care (of pin cleaning and iodine dressings) with no routine care in 56 patients undergoing uniplanar external fixators. No statistical difference was noted during the mean 55 day follow-up concluding that no benefit was inferred with their daily cleansing protocol.

Camilo[17] randomised two groups of 15 patients to iodine vs saline pin-site dressings in patients undergoing frame treatment for lengthening, transport and nonunions. After frame removal at a mean of 9 months, there was a per-patient PSI rate of 67% with iodine vs 47% normal saline which did not achieve statistical significance.

Subramanyam[18] investigated several solutions used for the cleansing of pin sites in circular fixators. They followed the patients up until the frames were removed, however divided their 114 participants into four difference groups, in the end concluding that per-PSI rates were not different between solutions comprising of no solution, iodine, sulphadiazine or chlorhexidine.

Jalon[19] randomised 128 patients and 568 pins to compare iodine and chlorhexidine for pin-site care in patients undergoing external fixation for clean or contaminated surgeries. Ultimately, they reported a 62% per-patient PSI in the chlorhexidine group vs a 68% PSI in the iodine group declaring no statistical difference.

Ferguson[20] reports the results of the PINS trial, a multicentre RCT recruiting 116 patients to compare the impact Dermol emollient pin-site dressing solution vs a control of standard chlorhexidine treatment. The findings demonstrated a 44% per-patient PSI in the Dermol group vs 40% in the chlorhexidine group with no statistical significance found.

Pommer[21] explored the impact of hydroxyapatite (HA) pins in comparison to uncoated pins over a minimum of 12 weeks in patients with monolateral fixators undergoing distraction osteogenesis. Twelve per cent of uncoated pins developed infection, and 13% were loose compared with 0% loosening or infection in the HA-coated pins ($p \leq 0.001$).

Piza[22] also investigated the role of HA-coating on preventing PSI. Through quasi-randomisation in children who were undergoing lengthening for skeletal dysplasia, they observed 322 pin sites over a mean of 530 days concluding that the 40% per-pin PSI in HA-coated pins was statistically comparable to the 43% in uncoated pins.

Davies[23] employed a nonrandomised trial to compare wire insertion techniques in 120 patients. They found that the normal handling of wires, with continuous power insertion of wires and dry dressings, resulted in an 89% per-patient infection rate. This was compared to nontouch lower-energy pulsed and cooled insertion with chlorhexidine cleaning, and regular dressing changes had a 65% per-patient infection rate ($p \leq 0.001$).

Coester[24] sought to evaluate the antibacterial effects of silver on coated pins via RCT in 19 patients with tibial monolateral fixators for trauma. They concluded that the 30% infection rate in silver-coated (SC) pin sites was insignificant compared to the 21% of stainless steel pin sites after a mean of 4 months.

W-Dahl[25] randomised a different-type conical half-pin fixation and self-drilling half pins, again using patients undergoing tibial osteotomies with a monolateral fixator with a mean duration again of almost 100 days. Again, she found no difference in the PSI rate between groups (defined as days of antibiotics) with means of 7 and 10.5 days of antibiotics for conical and self-drilling pins, respectively (Flowchart 1) (Table 2).[6]

Pin Care

Eleven studies evaluated interventions pertaining to care of pin sites are outlined in Table 3. These can be categorised into those exploring pin-site dressings and pin-care regimes.

Pin-care Solutions

Four studies (Patterson,[14] Camilo,[17] Cavusoglu[15] and Henry[12]) explored a range of options for the type of cleansing solution (Table 3). Pin-site infection rates ranged from 4 to 67% amongst these trials. The only study demonstrating any superiority amongst solutions was Patterson et al.,[14] who found a significant reduction in PSI when combining hydrogen peroxide with Xeroform dressings. This reduction was not demonstrated in those using the same solution with standard gauze dressing, nor the use of Xeroform dressings with other solutions.

Pin-care Dressings

Seven studies (Chan,[8] Yuenyongviwat,[9] Ogbemudia,[10] Lee,[11] Subramanyam,[18] Patterson[14] and Ferguson[20]) explored pin-site dressing care (Table 4). Statistical superiority with reduction in PSI by 16% was demonstrated by Ogbemudia[10] when exploring the addition of sulphadiazine to chlorhexidine dressings. In the second study with positive findings, the addition of polyhexamethylene biguanide (PHMB) to gauze dressing reduced PSI rate in the study by Lee et al.[11]

Notably, one study (Subramanyam)[18] used the same plain gauze dressings, but applied layers of antiseptic solutions designed to remain *in situ*, so has been considered as a dressing protocol. Caution should be taken when interpreting the dressing results from Patterson,[14] as these dressing were used across three pin-cleaning regimes.

Pin-care Regimes

Three studies (Subramanyam,[18] W-Dahl[13] and Camathias[16]) explored frequency of pin caring regimes (Table 5). Caution should be taken when interpreting Subramanyam,[18] as the dressing frequency was trialled across four dressing interventions.

Four studies compared the type of half pin used and the impact on PSI and loosening (Table 6). Pommer[21] observed a statistically significant reduction in PSI when using HA-coated half pins (0%) compared to when using uncoated pins (12%). Additionally, a subgroup analysis from Chan[8] found the PSI rate within their study (which was designed to explore pin-care regimes) to be 24% with half pins compared to 15% with fine wires (RR, 1.61; $p = 0.001$).

Pin-insertion Techniques

One study (Davies)[23] investigated pin-insertion techniques where patients were randomised into groups. The control group followed local PSI care guidelines which involved normal handling of wires/pins, continuous drilling with irrigation, bone swarf removal, application of dry dressings for 48 hours followed by daily cleaning with saline, crust removal and no dressings applied thereafter unless exudate was observed. The intervention group followed the technique used by the Russian Ilizarov Scientific Centre for Restorative Traumatology and Orthopaedics which involved nontouch handling of wires/pins, pulsed drilling with irrigation, bone swarf removal, chlorhexidine pin-site dressings and site cleansing for 3 days with alcohol solution followed by occlusive pressure dressings changed every 7–10 days. A statistically significant reduction in PSI was observed, with 48 out of 74 (65%) patients in the Russian method group having PSI compared to 41 out of 46 in the control group (89%) ($p = 0.03$). The authors conclude that the Russian Ilizarov Scientific Centre for Restorative Traumatology and Orthopaedics protocol improves rates of PSI and advocates its adoption.

Discussion

There are several variables to consider regarding the incidence of PSI which can be attributable to pin-site dressings, frequency of dressings, type of pin used and pin-insertion technique.

Sulphadiazine was found to be beneficial in reducing PSI,[10] which has since been observed in other studies.[9] Daily pin-site care was also found to not be superior to weekly care in several studies. Nonstatistically significant reduction in PSI was observed when using daily care.[16,18] W-Dahl noted no superiority in daily vs weekly care,[13] corroborated by similar findings where 4% PSI was observed with no pin-site care (Gordon).[26] In studies evaluating half pins, Pommer noted a statistically significant reduction in PSI when using HA coating,[21] a phenomenon not replicated by Piza.[22] The use of silver coating or different half pin designed (conical or self-drilling) was not observed to impact PSI; however, the numbers in these trials are small and difficult to draw definitive conclusions from Khan who observed the use of Schanz pins had increased rates of PSI compared to K wires,[27] and it is difficult to draw conclusions from this study as there is limited information given about other variables impacting pin-site care. Valentin[28] observed significantly higher rates of PSI in half pins, compared to both fine-wire pin sites and hybrid fixators.[28] Due to the retrospective nature of the study, the impact of confounding variables and their impact upon PSI are difficult to quantify. Huston observed 13% PSI in tensioned hybrid fixators;[29] however, no control group means it is difficult to compare these results with those of another study.

It was observed that PSI incidence was reduced when adding sulphadiazine to chlorhexidine dressings.[10] Sulphadiazine dressings alone were observed to result in no statistically significant reduction in PSI compared to dry dressings.[9] Adding polyhexamethylene biguanide (PHMB) to gauze dressing was also observed to reduce PSI;[11] however, this may have been biased due to the observational nature of the study. Subramanyam[18] demonstrated that the use of antiseptics had no benefit in reducing PSI incidence; similarly Henry[12] noted the lowest incidence of PSI occurred with no solution used. This is contradicted by Davies[23] in which it was observed that using antiseptic solution on pin sites reduced the incidence of PSI compared to normal saline.[23] However, it is difficult to draw a definitive conclusion as the groups in this study underwent different methods of pin insertion which could have impacted PSI incidence.

This study observed that daily pin-site care was not superior to weekly pin-site care. Subramayan[18] observed a slight reduction

Table 3: Solutions used for cleaning pins

Author	*Interventions*	*No. of patients*	*No. of pin sites*	*Patient population*	*Pin-care regime*	*Findings*
Patterson, 2005[14]	Hydrogen peroxide	22	122	Consecutive adults and children treated for factures	Twice daily dressing changes (with exception of 1 subgroup with change as required). Cleansing subgroups as per Table 4	Hydrogen peroxide–4% infection rate with Xeroform dressing, 28% with cause
	Antibacterial soap and water	29	174			Soap–12% infection rate with Xeroform dressing, 14% with cause
	0.9% saline	30	173			Saline–20% infection rate with Xeroform dressing, 32% with cause
						Hydrogen peroxide group had significantly reduced PSI, but only when combined with Xeroform dressings
Camilo, 2015[17]	10% polyvinyl-pyrrolidone-iodine	15	ND	Adults and adolescents with Ilizarov frames (indications ND)	Patient-led cleaning of pins with saline post-shower before dressing applied (frequency ND)	66.7% PSI with polyvinylpyrrolidone-iodine
	0.9% saline	15	ND			46.7% PSI with saline
						(NS)
Cavusoglu, 2009[15]	10% polyvinyl-pyrrolidone-iodine	19	300	Adults with Ilizarov fixators for tibia fractures	Patient-led pin cleansing with no dressings	50.7% minor infection and 3.5% major infections with iodine
					First 15 days: Every 3 days with iodine, no dressings, no showers	43.6% minor infections and 3.7% major infections with soap
					After 15 days: Daily showers and cleansing with experimental solution	(NS)
	Soap*	20	310			
Henry, 1996[12]	None	ND	40	ND	Daily pin care with the experimental solution	7.5% PSI with no solution
						25% PSI with saline
						17.5% PSI with alcohol
						(No statistics reported)
	0.9% saline	ND	40			
	70% alcohol	ND	40			
	10% povidone-iodine solution					

*Following 15 days treatment with 10% polyvinyl-pyrrolidone-iodine; ND, not declared; NS, not statistically significant

Table 4: Pin-site dressings

Author	*Interventions*	*No. of patients*	*No. of pin sites*	*Patient population*	*Pin-care regimes*	*Findings*
Chan, 2009[8]	Diluted betadine dressings	30	ND	Adults and children undergoing distraction osteogenesis using fine wires and half pins	ND	Overall infection rate 18%
	Saline dressings	30	ND			19% PSI with betadine dressings, 17% with saline (NS)
Yuenyongviwat, 2009[9]	0.5% sulphadiazine ($n = 15$)	15	ND	Open fractures definitively managed with external fixators	Daily saline then sulphadiazine dressing from day 3	43.7% PSI with sulphadiazine dressings
	Dry dressing ($n = 15$)	15	ND		Daily dry dressing (with optional crust removal) from day 3	40% dry dressings (NS)
Ogbemudia, 2010[10]	Chlorhexidine dressing	38	ND	Patients aged 5–75 requiring external fixation	Experimental dressing for 72 hours then reapplied and changed weekly 5 days of postoperative antibiotics	23.7% PSI with chlorhexidine alone
	5% chlorhexidine and 1% sulphadiazine	38	ND			7.9% PSI with chlorhexidine and sulphad-iazine Statistically significant $p = 0.03$
Lee, 2012[11]	Polyhexamethylene biguanide (PHMB) gauze	22	216	Patients undergoing limb lengthening/ deformity correction using external fixation	Daily dressings	Overall infection rate 2.6% 1% PSI with PHMB dressings
	Plain gauze	18	267			4.5% PSI with plain gauze dressings $p = 0.00$
Subramanyam, 2019[18]	10% povidone iodine*	27	561	All patients without infection undergoing fine-wire constructs	Once weekly or once daily (sub-stratified)	44% patients developed PSI with
	1% silver sulphadiazine	27	570			37% patients developed PSI with silver sulphadiazine dressings
	1% chlorhexidine	30	594			40% patients developed PSI with chlorhexidine dressings
	No solution	30	638			33% patients PSI with plain gauze dressings (NS)
Patterson, 2005[14]	3% bismuth tribromophenate and petroleum gauze (Xeroform)	42	192	Consecutive adults and children treated for factures	Twice daily dressing changes (with exception of 1 subgroup with change as required). Cleansing sub-groups as per Table 3	14% PSI in patients with Xeroform dressings (across H_2O_2, saline and soap pin cleaners)
	Plain gauze	50	235			25% PSI in patients with plain gauze dressings (across H_2O_2, saline and soap pin cleaners and no cleaning solution) No statistical comparison declared

(Contd...)

Table 4: (*Contd...*)

Author	*Interventions*	*No. of patients*	*No. of pin sites*	*Patient population*	*Pin-care regimes*	*Findings*
Ferguson, 2021[20]	0.5% chlorhexidine	59	ND	>16-year-old patients with tibial fractures treated with circular frame	Patient-led weekly dressings; Crust retained, chlorhexidine or Dermol pin dressing	40% PSI in CHX group 44% PSI in DML group (NS) Thicker epidermis associated with PSI 7% pin-site reaction to chlorhexidine

*Under plain gauze; CHX, chlorhexidine; DML, Dermol; ND, not declared; NS, not statistically significant

in PSI using daily care compared to weekly care, but this was not statistically significant.[18] W-Dahl[13] observed no differences in frequency or severity in PSI when comparing daily and weekly care.[13] Camathias[16] also observed a slight reduction in PSI when performing daily care compared to no care, which was not statistically significant.[16] These findings are corroborated by Gordon,[26] where no pin-care regime was undertaken except daily showering, and an incidence of 4% PSI was found per observation.[26] This may be biased due to there being no control group, so is difficult to compare to the other studies examining frequency of pin-site care.

Regarding the type of half pin used, Piza[22] observed a 76% reduction in pin loosening in pins coated in HA compared to uncoated pins, but noted no difference in the incidence of PSI between study groups.[22] This is contradicted by Pommer[21] which observed a statistically significant reduction in PSI using HA-coated pin.[21] Moroni[30] also noted a reduction in PSI in tapered HA-coated pins compared to tapered noncoated pins.[30] No superiority was noted between SC and SS pins.[24] Khan[27] noted a statistically significant reduction in PSI using K-wires compared to Schanz pins.[27] Limited conclusions can be drawn from this study as it does not state information on pin-site dressings, cleansing solutions or pin-insertion method which could impact upon findings. Valentin[28] observed significantly higher rates of PSI in half pins, compared to both fine-wire pin sites and hybrid fixators.[28] This study is retrospective in nature; hence, there are numerous variables that may have changed throughout the study contributing to high rates of PSI. These findings were validated by Huston[29] observing 13% PSI when using tensioned hybrid wire fixators.[29] There is likely to be less variability in results in this study due to their being a sole surgeon; however, there was no control group, so it is difficult to compare these results to another patient cohort.

Davies et al.[23] noted a statistically significant reduction in PSI when inserting pins via pulsed drilling with irrigation compared to continuous drilling with irrigation.[23] It is difficult to draw definitive conclusions from this study as there were multiple confounders between study groups. Nevertheless, the use of pulsed insertion, chlorhexidine irrigation and dressings appeared to have a significant improvement in associated PSI.

There are several limitations in drawing conclusions from these studies due to the wide variety of factors impacting PSI; in particular, the aftercare is not the sole influencer in the incidence of pin-site issues. In a similar vein, there are no set definitions of PSI due to the range of clinical presentations. There is also no standardised scoring system, with a variety of systems being adopted by different hospitals. Checketts and Otterburn[31] is the most recent scoring system being used, but literature suggests it is difficult to differentiate between grades of infection, challenging its reliability.[32] This eludes to wider issues in the diagnosis of PSI, as there are no set clinical or laboratory criteria required for a diagnosis. Some checklists, including Checketts and Otterburn,[31] also use likely suitable treatment as criterion to deem the grade of PSI. This limits the clinical utility of a classification, given that it may only be with retrospect following treatment that the severity of PSI is qualified.

The known multitude of attributable factors which influence PSI results in heterogeneity amongst studies as pin-care protocols vary greatly between centres, of which few studies detail these with accuracy. Typical features which remain unknown even amongst these highest quality studies include intraoperative technique, dealing with crusts, institutional setting of pin-site care, sterility of dressing care and policy on showers. There also remains

Table 5: Pin-care regimes

Author	Interventions	No. of patients	No. of pin sites	Patient population	Pin-care regimes	Findings
Subramanyam, 2019[18]	Weekly dressing changes	ND	1,278	All patients without infection undergoing fine-wire constructs	Patient-led cleaning with saline then with subgrouped as per Table 4 (silver sulphadiazine, povidone iodine, chlorhexidine)	10 patients with PSI in control group (33%) 10 patients with PSI in silver sulphadiazine group (37%) 12 patients with PSI in povidone iodine group (44%) 12 patients with PSI in chlorhexidine group (40%) (NS)
	Daily dressing change		1,224			
Camathias, 2012[16]	Daily care	ND	101	Half-pin constructs for open and closed fractures Adults and Children	Crusts around pin removed with sterile saline irrigation, Sterile dressing presoaked in povidone–iodine applied	35% of all pin sites had secretions/granulation tissue–NS between groups 75% PSI with no care and 79% receiving daily care (NS) Removal torque with no care 60 N cm vs 75 N cm with daily care (NS) Osteolysis observed in 6 pins with no care group vs 7 in daily care
	No care	ND	103			
W-Dahl, 2003[13]	Daily care	27	108	Monolateral fixators in adults undergoing proximal tibial osteotomies for knee arthritis	Nurse-led pin care as required as inpatient and outpatient Saline clean and absorbent dressing	Daily dressings: Grade I = 14% Grade II = 4% >Grade II = 0% Weekly dressings: Grade I = 10% Grade II = 3% >Grade II = 0% No significant difference in pain (VAS) Metaphyseal pins higher infection rate (p <0.001, RR = 1.5)

NS, not statistically significant; VAS, visual analogue score

Table 6: Types of pin used

Author	*Interventions*	*No. of patients*	*No. of pin sites*	*Patient population*	*Pin-care regimes*	*Findings*
Pommer, 2002[21]	HA-coated half pins	23	165	Adults undergoing distraction osteogenesis with monolateral fixator	Daily cleaning with Ringer's solution and absorbent cotton dressing	20 pins had PSI in the control group (12%)
	Uncoated	23	169			No PSI in the HA group (0%) Statistically significant
W-Dahl, 2008[25]	Conical half pins*	25	100	Monolateral fixators in adults undergoing proximal tibial osteotomies for knee arthritis	Nurse led, weekly clean with chlorhexidine and 70% alcohol and chlorhexidine dressing	Grade I Infection = 18% pins in 48% patients in conical pins vs 20% pins in 44% patients in self-drilling ($p = 0.9$, significance not stated) Grade II infection = 9% pins in 20% patients in conical pins vs 11% pins in 28% in self-drilling ($p = 0.8$, significance not stated) Duration of antibiotics: Conical 7 days vs self-drilling 10.5 days ($p = 0.16$, significance not stated) Mean VAS conical 5 at rest, 12 with activity vs self-drilling 19 rest and 32 activity ($p = 0.01$, significance not stated) Loosening: Conical 2% loose vs self-drilling 9% ($p = 0.03$, significance not stated)
	Self-drilling, self-tapping half pins (XCaliber, Orthofix)*	25	97			
Piza, 2004[22]	HA-coated half pins	23	161	Children undergoing lengthening for skeletal dysplasia	ND	72% PSI in HA vs 93% in uncoated (NS)
	Uncoated conical	23	161			22% PSI caused by pseudomonas in HA vs 12% in uncoated ($p = 0.037$, statistically significant)
Coester, 2006[24]	SC half pins	ND	33	Fractures definitely managed with external fixators	ND	30% PSI in SC half pins
	Stainless steel (SS) half pins	ND	33			21% PSI in SS pins (NS)

*HA in metaphysis, uncoated diaphysis; HA, hydroxyapatite; ND, not declared; NS, not statistically significant; SC, silver-coated; SS, stainless steel; VAS, visual analogue score heterogeneity between study reporting methods, in which most studies report infections per-pin site which helps power a study adequately, but doesn't account for individuals who are susceptible to multiple PSIs. Alternatively, some report per-patient rates often giving a higher perception of PSI rate and may 'cloud-over' a more sensitive analysis.

Another limitation is mode of pin care, in particular given that some studies specify this as patient-led or nursing-led leading to several confounders. Results focussing on patient-led cleansing do not account for issues with compliance to treatment regime, making these results difficult to compare to those with nurse-led cleansing as the mode of care. Issues also are noted in comparing results from studies observing frequency of pin cleansing. It is difficult to compare results from studies regarding frequency of pin cleansing as they may use different cleansing solutions or pin-site dressings; hence, a definitive comparison cannot be made. The impact of surgeon intraoperative technique on PSI incidence is also difficult to quantify but may explain the large range of PSI rates observed across the studies. Further studies are needed to determine the impact of these factors, as well as the creation of a standardised scoring system.

Conclusion

This systematic review details the best quality evidence for the prevention of PSI. Whilst any synthesis of literature is limited by the quality of studies pooled, this work outlines that weekly care is as effective as daily care, and low-energy pin-insertion techniques are superior. There remains unanswered questions regarding the most effective pin-care regime, solution and dressing; however, sulphadiazine appears to demonstrate the most promise. A well-designed clinical trial with well-matched and controlled groups exploring pin-site cleansing and/or dressings is warranted to answer this question. A rigorous reporting not only of the interventions, but a precise documentation of a controlled regime for pin insertion, the setting/individuals performing the pin-site care, policies on showering, dealing with crusts and frequency of dressing changes will be necessitated.

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