

Buried Versus Exposed Kirschner Wires Following Fixation of Hand Fractures: 1 Clinician and Patient Surveys

WIRE Research Collaborative

Background: Fractures of the metacarpals and phalanges are common. Placement of Kirschner wires (K-wires) is the most common form of surgical fixation. After placement, a key decision is whether to bury the end of a K-wire or leave it protruding from the skin (exposed). A recent systematic review found no evidence to support either approach. The aim of study was to investigate current clinical practice, understand the key factors influencing clinician decision-making, and explore patient preferences to inform the design of a randomized clinical trial.

Methods: The steering group developed surveys for hand surgeons, hand therapists, and patients. Following piloting, they were distributed across the United Kingdom hand surgery units using the Reconstructive Surgery Trials Network.

Results: A total of 423 hand surgeons, 187 hand therapists, and 187 patients completed the surveys. Plastic surgeons and junior surgical trainees preferred to leave K-wires not buried. Ease of removal correlated with a decision to leave wires exposed, whereas perceived risk of infection correlated with burying wires. Cost did not affect the decision. Hand therapists were primarily concerned about infection and patient-related outcomes. Patients were most concerned about wire-related problems and pain.

Conclusion: This national survey provides a new understanding of the use of K-wires to manage hand fractures in the United Kingdom. A number of nonevidence-based factors seem to influence the decision to bury or leave K-wires exposed. The choice has important clinical and health economic implications that justify a randomized controlled trial. (*Plast Reconstr Surg Glob Open* 2018;6:e1747; doi: 10.1097/GOX.0000000000001747; Published online 16 April 2018.)

The WIRE Steering Group (in alphabetical order) comprises: Matthew D. Gardiner, Sonya Gardiner, Fadi Issa, Abhilash Jain, Hawys Lloyd-Hughes, Theodore Pezas, Jeremy N. Rodrigues, Justin C. R. Wormald. The WIRE Local investigators (in alphabetical order) comprises: Frank Acquaah, Neil Brierley, Shixin Bickerton, Whitney Chow, Juliet Clutton, Samuel Coulson, Pat Crowley, Sarah Jayne Edmondson, Andy Fowler, Michael Gallagher, Sophie Howles, Jonathan Jones, Lubna Khan, Dharini Kulendran, Clare Langley, Robert Manton, Mohamed Mohamed, Lisa Ng, Andrej Salibi, Gujral Sameer, Nic Segaren, Kavita Sharma, Andreas Shiatis, Kathryn Steele, Camilla Jay-Stewart, Cindy Suwito, Amy Tam, Arron Thind, Ryckie Wade, Natasha Wielogorska, Katie Young.

INTRODUCTION

After fractures of the distal radius and ulna, fractures of the hand are the second most common. They account for approximately 20% of all fractures and the incidence

peaks in early adulthood.¹⁻³ Placement of Kirschner wires (K-wires) is the most common form of surgical fixation, with open reduction and internal fixation (ORIF) being the second most common method.⁴⁻⁶ Once inserted, a key

Matthew D. Gardiner, Abhilash Jain, Jeremy N. Rodrigues, and Justin C. R. Wormald are at the Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, United Kingdom; Sonya Gardiner is at St Andrew's Centre for Burns and Plastic Surgery, Broomfield Hospital, Chelmsford, United Kingdom; Fadi Issa is at the Nuffield Department of Surgery, University of Oxford, Oxford, United Kingdom; Theodore Pezas is at Birmingham Children's Hospital, Birmingham, United Kingdom; and Hawys Lloyd-Hughes is at Department of Plastic Surgery, St Thomas' Hospital, London, United Kingdom.

Presented at the British Society of Surgery for the Hand (BSSH), Autumn Scientific Meeting 2016 in Cardiff, Wales.

Received for publication January 10, 2018; accepted February 13, 2018.

Copyright © 2018 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of The American Society of Plastic Surgeons. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

DOI: 10.1097/GOX.0000000000001747

Disclosure: The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by a grant from the British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS).

decision is whether to leave a short portion of the wire primarily exposed or cut short and buried beneath the skin. The wires are usually temporary and are removed within a few weeks. The perceived advantages of burying wires include patient comfort, reduced infection rate, earlier physiotherapy, and the ability to leave the wires in for longer periods.⁷⁻¹⁰ Conversely, an advantage of exposed wires is their easy removal in clinic rather than at a second procedure requiring anesthetic. This may reduce contact time and inconvenience for the patient, and financial cost to the health service.^{7,11} A recent systematic review found low-quality evidence comparing burying or leaving K-wires exposed in the upper extremity with regard to postoperative infection or other outcomes.¹² The aim of this study was to investigate current clinical practice, understand the key factors influencing clinician decision-making, and explore patient preferences to inform the design of a randomized control trial.

METHODS

The steering group developed bespoke surveys for hand surgeons, hand therapists, and patients. The “hand surgeon” and “hand therapy” surveys investigated aspects of unit and personal preferences for managing K-wires and the factors that influenced clinical decision-making to bury or leave K-wires exposed (see pdf, **Supplemental Digital Content 1**, which describes clinical practice survey for surgeons, <http://links.lww.com/PRSGO/A746>; see pdf, **Supplemental Digital Content 2**, which describes clinical practice survey for hand therapists, <http://links.lww.com/PRSGO/A747>; see pdf, **Supplemental Digital Content 3**, which describes the patient survey, <http://links.lww.com/PRSGO/A748>). The “patient” survey asked for the top 5 concerns they had about their K-wires. A pilot of the survey was undertaken at 2 hand surgery units. Respondents were asked to complete the survey and provide feedback on the questions. This process led to modification of the surveys. Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at Kennedy Institute of Rheumatology, University of Oxford.¹³ REDCap is a secure, web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.

A trainee collaborative approach was used to establish a reliable denominator list and representative response rate. The WIRE Collaborative was a group of trainees recruited from the Reconstructive Surgery Trials Network. The Reconstructive Surgery Trials Network is the U.K. clinical trials network for plastic surgery and hand surgery. Collaborators were asked to identify every hand surgeon, trainee hand surgeon, and hand therapist at their unit. Following this, they were provided with links to the surveys hosted on the REDCap system. In addition, they were asked to return 5 patient surveys. In total, 89 hand surgery

units were identified, and collaborators were recruited from 58 of these units.

Descriptive analysis was performed for all survey outcomes. For categorical data, contingency tables were built. As these were expected to comprise some cells with low numbers, they were analyzed using Fisher’s exact test. The association between variables and surgeons’ preference to bury or leave K-wires exposed was studied by calculating raw odds ratios (ORs) describing the effect of a single unit incremental increase (using the 1–9 scales of importance in the survey) in the subjective importance placed on the variable and surgeons’ preferences. All variables were entered as covariates in a multinomial logistic regression model.

To control for false-positive associations, a described method was used to adjust the *P* value threshold considered significant for each covariate in an analysis.¹⁴ An a priori false discovery rate (*Q*) of 20% was adopted. The covariates in the model were ordered by *P* value, and each covariate’s *P* value threshold was calculated using the formula $(i/m)*Q$, where ‘*i*’ was the rank of the covariate by *P* value and ‘*m*’ was the total number of tests (12 in each analysis).

RESULTS

A total of 797 survey responses were collected. This constituted 423 (53%) surgeons, 187 (23%) hand therapists, and 187 patients (23%) from 58 hand surgery units across the United Kingdom. A majority of both orthopedic and plastic surgeons had no preference (83% and 77%, respectively) for K-wire or ORIF as surgical management of metacarpal or phalangeal fractures (Table 1). For those with a preference, orthopedic surgeons favored ORIF and plastic surgeons K-wire fixation. Junior surgeons, who had a preference, favored K-wire fixation over ORIF. Overall, very few preferred ORIF to K-wires regardless of seniority or specialty. The

Table 1. Reported Preferences for Type of Fracture Fixation Dependent on Surgical Specialty or Seniority (n, %)

Specialty/seniority	No Preference	K-wire	ORIF
Plastic surgeon	247 (77.6)	60 (18.7)	12 (3.7)
Orthopedic surgeon	64 (83.1)	4 (5.2)	9 (11.7)
Consultant	176 (88.0)	14 (7.0)	10 (5.0)
Junior	137 (69.2)	50 (25.3)	11 (5.6)

Table 2. Reported Preferences for Buried Versus Exposed K-wire Fixation Dependent on Specialty, Seniority, or Unit Preference (n, %)

Specialty/seniority	No Preference	Buried	Exposed
Plastic surgeon	108 (33.6)	43 (13.4)	170 (53.0)
Orthopedic surgeon	38 (48.7)	8 (10.3)	32 (41.0)
Consultant	88 (44.0)	28 (14.0)	84 (42.0)
Junior	58 (29.1)	23 (11.6)	118 (59.3)
	No preference	Buried	Exposed
Unit	222 (55.8)	44 (11.1)	132 (33.2)

Table 3. Univariate and Multivariate Odds Ratios Describing the Association of Single-unit Increase in the Importance Placed on Covariates with Preferences to Bury K-wires Versus Having No Preference

Covariate	Univariate Odds Ratio (95% CIs)	Statistical Significance of Univariate Odds Ratio	Multivariate Odds Ratio (95% CIs)	Statistical Significance of Multivariate Odds Ratio	i/m × Q; P Threshold
Significant results in multivariate analysis					
Ease of wire removal	0.78 (0.68–0.90)	0.001	0.73 (0.59–0.90)	0.003	0.016
Risk of pin-site infection	1.56 (1.20–2.03)	0.001	1.50 (1.09–2.06)	0.013	0.033
Nonsignificant results in multivariate analysis					
Cosmesis	0.90 (0.75–1.07)	0.232	0.86 (0.68–1.10)	0.238	0.050
Preventing unwanted wire removal	0.88 (0.76–1.02)	0.081	0.89 (0.74–1.07)	0.201	0.067
Ease of hand therapy	1.14 (0.96–1.34)	0.128	1.14 (0.92–1.42)	0.240	0.083
Ease of dressing	1.08 (0.92–1.27)	0.335	1.15 (0.88–1.49)	0.313	0.100
Cost to the health service	0.96 (0.83–1.11)	0.577	1.15 (0.81–1.61)	0.427	0.117
No. patient admissions required	0.87 (0.75–1.01)	0.061	0.91 (0.72–1.15)	0.439	0.133
Cost to the patient	0.93 (0.81–1.09)	0.414	1.07 (0.79–1.44)	0.675	0.150
Use of health service resources	0.91 (0.79–1.04)	0.172	0.99 (0.75–1.32)	0.953	0.167
Pain	1.13 (0.97–1.32)	0.116	1.00 (0.80–1.26)	0.979	0.183
Risk of bone infection	1.32 (1.05–1.66)	0.016	1.00 (0.75–1.33)	0.994	0.200

Results have been ordered by *P* value for multivariate OR. Statistically significant results are emboldened.

majority of plastic surgeons expressed a preference to leave K-wires exposed (53%) with 34% reporting no preference (Table 2). In contrast, 41% of orthopedic surgeons expressed a preference to leave K-wires exposed, and 49% of orthopedic surgeons expressed no preference. Only 13% of plastic surgeons and 10% of orthopedic surgeons preferred to bury wires. The majority of junior surgeons preferred to leave the wires exposed (59%), whereas the consultant body was divided between exposed (42%) and no preference (44%). From the responses, only 55.8% of units have a preference, with the remaining units allowing surgeons to decide on a case-by-case basis.

A multinomial logistic regression analysis was performed with surgeon burying preference as the dependent variable and the key variables affecting this decision as covariates. Concerns regarding the risk of pin-site infection significantly increased the likelihood of preferring to bury K-wires (versus preferring not to bury K-wires or having no preference), as shown in Table 3 [adjusted OR (adjOR), 1.50, *P* = 0.01]. The nature of the regression is

such that this finding is independent of whether the individual was concerned about the risk of osteomyelitis, pain, ease of dressing change, and the other covariates in the model. Conversely, we found that increased consideration of the ease of K-wire removal was associated with less inclination to bury K-wires (adjOR, 0.73; *P* ≤ 0.005). In keeping with this, the ease of removal was positively associated with a preference to leave the K-wire exposed (adjOR, 1.4; *P* ≤ 0.001; Table 4). The association between the consideration of the aesthetic outcome and preference to bury the K-wire was not significant once correction for multiple testing was applied (adjOR, 1.2; *P* = 0.03). The survey items that were related to service provision and economic impact did not seem to influence the responder's preference. Clinicians and therapists were most likely to choose a preference of burying or not based on clinical (pin-site infection, osteomyelitis) and functional (range of movement, grip strength) outcomes.

A majority of surgeons (83%) reported always giving antibiotics on induction when performing K-wire fixation and 33% always prescribe a postoperative course. Most

Table 4. Univariate and Multivariate Odds Ratios Describing the Association of Single-unit Increases in the Importance Placed on Covariates with Preferences to Not Bury K-wires Versus Having No Preference

Covariate	Univariate Odds Ratio (95% CIs)	Statistical Significance of Univariate Odds Ratio	Multivariate Odds Ratio (95% CIs)	Statistical Significance of Multivariate Odds Ratio	i/m × Q; P Threshold
Significant results in multivariate analysis					
Ease of wire removal	1.29 (1.16–1.44)	< 0.001	1.39 (1.20–1.61)	< 0.001	0.016
Nonsignificant results in multivariate analysis					
Cosmesis	0.95 (0.90–1.12)	0.947	1.20 (1.01–1.42)	0.034	0.033
Risk of bone infection	0.78 (0.70–0.87)	< 0.001	0.85 (0.72–1.00)	0.056	0.050
Preventing unwanted wire removal	0.91 (0.83–1.00)	0.060	0.89 (0.78–1.01)	0.072	0.067
Cost to the patient	1.06 (0.96–1.17)	0.265	0.84 (0.69–1.02)	0.084	0.083
Ease of hand therapy	0.88 (0.79–0.98)	0.014	0.87 (0.75–1.02)	0.089	0.100
No. patient admissions required	1.14 (1.04–1.25)	0.005	1.13 (0.96–1.33)	0.141	0.117
Risk of pin-site infection	0.80 (0.72–0.89)	< 0.001	0.90 (0.76–1.07)	0.241	0.133
Use of health service resources	1.17 (1.06–1.28)	0.001	1.08 (0.91–1.28)	0.358	0.150
Cost to the health service	1.09 (0.99–1.20)	0.094	0.98 (0.80–1.19)	0.817	0.167
Ease of dressing	0.98 (0.88–1.09)	0.663	0.99 (0.83–1.18)	0.908	0.183
Pain	0.91 (0.82–1.01)	0.062	1.00 (0.85–1.17)	0.999	0.200

Results have been ordered by *P* value for multivariate OR. Statistically significant results are emboldened.

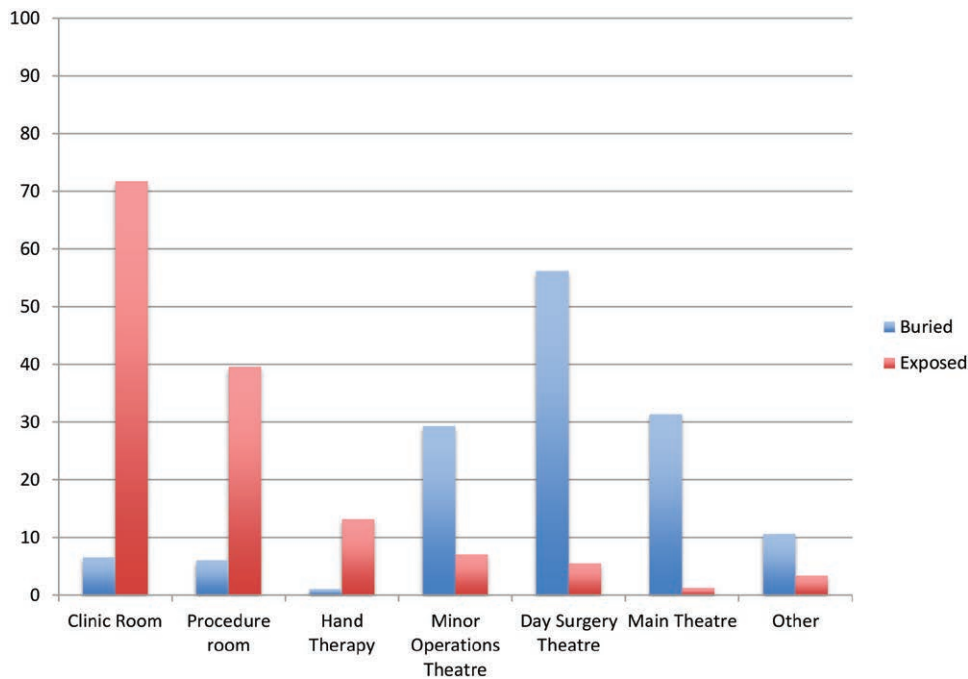


Fig. 1. Location of K-wire removal.

surgeons reported removing exposed K-wires from phalangeal fractures at 4 weeks (60%) and buried wires at 4 weeks (32%) or 6 weeks (28%). For metacarpal fractures, nonburied wires were most often removed at 4 weeks (60%), whereas buried wires were removed at 4 weeks (28%) or 6 weeks (28%). The reported follow-up periods were 6 weeks (17.4%), 8 weeks (20.3%), or 12 weeks (40.1%). Exposed wires were most commonly removed in an outpatient setting, whereas buried wires were most commonly removed in theater (Fig. 1).

Hand therapists mostly had no preference in terms of whether the wire was buried or not (60%). Pin-site infection and osteomyelitis were major concerns for this group. The hand therapists generally rated patient-related outcomes as more important than the clinician group, including quality of life, patient satisfaction, and return to normal activity. Range of movement was also a key outcome of importance for hand therapists, but cosmesis did not score highly in the hand therapy group compared with the clinicians.

Patients in both the buried and exposed wire groups expressed similar concerns (Fig. 2). The primary concerns were related to the K-wire, their recovery, and associated pain. Patients with exposed K-wires were proportionally more concerned about the risk of infection than the other group.

DISCUSSION

This study used a trainee collaborative approach to assess the current U.K. clinical practice for managing K-wire fixation of metacarpal and phalangeal fractures of the hand. It identified areas of common practice. These included the lack of surgeon preference for K-wire or ORIF

for managing hand fractures and the use of antibiotics on induction. It also highlighted areas of clinical variation, including postoperative antibiotic prescribing, location of K-wire removal, and follow-up regimes. The WIRE Study was the first U.K. hand surgery study to take a trainee-led collaborative approach, which has been used with great success in other surgical specialties.¹⁵ The survey response rates were markedly higher than a comparable study from our network investigating preferences for managing mallet finger injuries.¹⁶ The collaborative model improved survey methodology through collection of denominator lists and by directly engaging clinicians and patients when completing the survey.

Half of the surgeons expressed a preference for burying K-wires with the other half either having no preference or reporting a preference for leaving wires exposed. This uncertainty reflects the clinical equipoise and low-quality evidence available to inform decision-making.¹² Risk of infection was identified as an independent variable in the decision making of those surgeons preferring to bury wires. Infection was also a major concern of patients. However, infection rates are reported to be low in other studies, and it is unclear whether burying K-wires reduces infection rates in the hand. A recent retrospective case review of 695 patients with buried and exposed K-wires in hand and wrist fractures found that exposed K-wires were more likely to be treated for a pin-site infection than buried wires. Exposed K-wires in metacarpal fractures were the most likely to require antibiotic treatment.¹⁷ Another recent retrospective series of 1,213 patients, with K-wires left exposed following fixation of hand and wrist fractures, reported that 85 (7%) developed a pin-site infection.¹⁸ Five (0.4%) of these patients required further surgery, 3 for osteomyelitis. The rest were successfully treated with

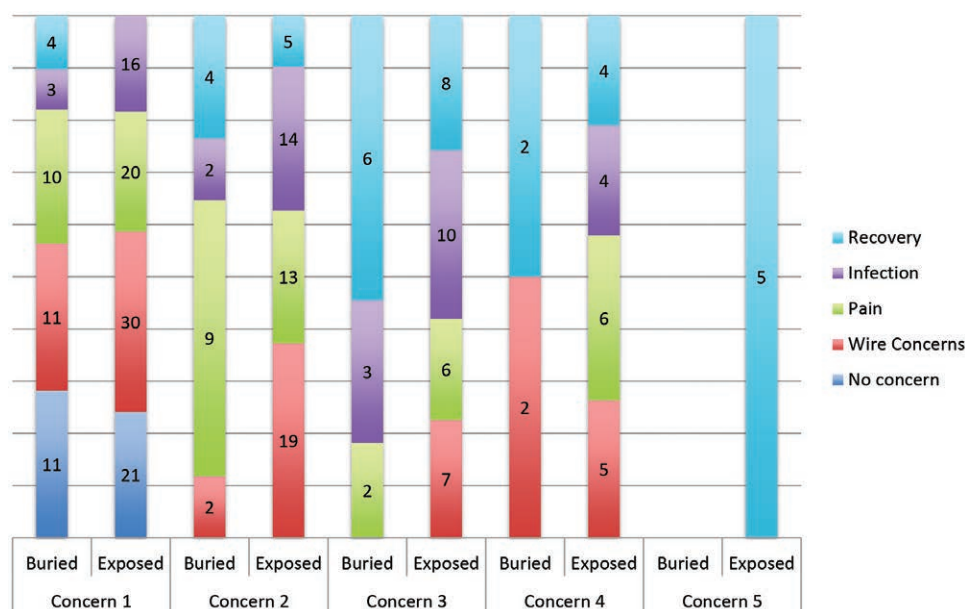


Fig. 2. Summary of patient concerns. Patients were asked about their main concerns following their own hand fracture fixation with either buried or nonburied K-wires. Free text responses were grouped into themes: “wire related” included wire removal, wire moving, wire catching, and successful fixation of fracture. “Recovery” included further surgical intervention, hand function, return to work, need for further surgery. “Pain” included pain and skin irritation. “Infection” included concerns about the wire becoming infected.

antibiotics. Botte et al.¹⁹ reported an infection rate of 7% in a series of 137 patients with exposed K-wire fixation of hand fractures. Koç et al.⁷ reported infection rates of 10% in exposed and 9% in buried K-wires when used in hand fracture fixation. A number of studies use the Oppenheim Classification of pin-site infection, or a modification. It remains unclear whether a pin-site infection has any long-term effect on patient outcomes.

Ease of wire removal was an independent variable in the decision making of those surgeons preferring to leave wires exposed. Removal of buried wires usually requires admission to hospital for a further procedure. This is inconvenient and costly for both patient and health service. A U.K.-based cost-analysis by Koç et al.⁷ of metacarpal and phalangeal fractures reported a cost per patient of £235.51 and £90.80 for buried wires and exposed wires, respectively. Despite this clear cost difference, surgeons in this study did not score economic factors as being important in the decision-making process.

The survey identified a trend toward surgical factors determining the choice to bury or leave K-wires exposed. This included risk of pin-site infection, osteomyelitis, range of motion, and grip strength. Patient-related outcomes including the Disabilities of the Arm, Shoulder and Hand scores, cosmesis, quality of life, return to normal function, and postoperative pain did not seem to have any significant impact on the decision-making process. In contrast to the surgeon responses, hand therapists’ responses highlighted their interest in the impact on patient satisfaction and quality of life.

Limitations of the study include the geographical restriction to the United Kingdom. The “event rate,” which

in this case was the preference to bury K-wires, was lower than had been anticipated. Convention suggests that studies should have 10 events per covariate; the regression analysis performed in the present study might be considered underpowered.²⁰ However, the validity of this heuristic has been challenged, and lower event rate:covariate ratios may be acceptable.²¹ The other option would have been to only analyze a restricted number of covariates, or to generate a parsimonious set using stepwise methods. Neither of these options were considered appropriate for an exploratory study. Instead, the potential for under powering and over fitting in this study was accepted. Our ordinal scales of variables were treated as covariates in the regression analysis rather than as factors, despite not having interval-level measurement properties demonstrated. In the absence of clear a priori hypotheses about cutoffs in the scales, and a desire to avoid exacerbating potential under powering, this was considered reasonable.

CONCLUSIONS

This trainee-led, collaborative national survey of clinicians and patients has identified key areas of clinical variability and uncertainty in the management of patients undergoing K-wire fixation of hand fractures. Decisions to bury or leave K-wires exposed are based on surgical dogma rather than evidence. Surgeon-centric factors seem to outweigh patient center factors in the decision-making process. Our findings along with further public and patient engagement, funded by the British Association of Plastic, Reconstructive and Aesthetic Surgeons, will be used to develop a protocol for a randomized clinical trial.

Matthew D. Gardiner, MA, PhD, FRCS(Plast)

Kennedy Institute of Rheumatology
Nuffield Department of Orthopaedics,
Rheumatology and Musculoskeletal Sciences (NDORMS)
Old Road Campus, Oxford, OX3 7FY
E-mail: matthew.gardiner@kennedy.ox.ac.uk

CONTRIBUTOR STATEMENT

SG, FI, MDG, HLH, JCRW and AJ conceived the idea; SG, HLH, JCRW, MDG, FI, TP, JNR and AJ formed the steering group and were involved in every aspect of patient and public engagement, protocol design and delivery of the project; SG and MDG programmed REDCap; JNR performed the statistical analysis; JCRW and MDG drafted the manuscript, all members of the steering group revised the manuscript and act as guarantors. WIRE Collaborators produced the denominator lists, ensured surgeons and therapists completed the surveys and identified patients to survey.

ACKNOWLEDGEMENTS

The Steering Group acknowledges the following contributors: Ben Dean, Lewis Dingle, Roisin Dolan, Shakeel Dustagheer, Jessica Harvey, Alex Reid, Andrew Robinson, Daniel Ryan, and thank the following units for participating in the study: Addenbrooke's Hospital, Arrowe Park Hospital, Bradford Royal Infirmary, Broomfield Hospital, Cardiff University Hospital Wales, Chelsea and Westminster Hospital, Derriford Hospital, Glasgow Royal Infirmary, Gloucester Royal Hospital, Hull Royal Infirmary/Castle Hill Hospital, James Cook University Hospital, John Radcliffe Hospital, Leeds General Infirmary, Leicester Royal Infirmary, Lincoln County Hospital, Mater Misericordiae, Morriston Hospital, New Pinderfields Hospital, Norfolk and Norwich University Hospital, Peterborough City Hospital, Pulvertaft Hand Centre, Queen Alexandra Hospital, Queen Elizabeth Hospital, Queen Victoria Hospital, Queen's Medical Centre, Royal Berkshire Hospital, Royal Devon and Exeter Hospital, Royal Free Hospital, Royal Preston Hospital, Royal Stoke Hospital, Royal Victoria Infirmary, Salisbury District Hospital, Southampton General Hospital, Southmead Hospital, St George's Hospital, St James's Hospital, St John's Hospital at Howden, St Mary's Hospital, St Thomas' Hospital, Stoke Mandeville Hospital, The Countess of Chester Hospital, Ulster Hospital, The Robert Jones and Agnes Hunt Orthopaedic Hospital, The Lister hospital, University Hospital Coventry, Wexham Park Hospital, Whiston Hospital.

REFERENCES

- Karl JW, Olson PR, Rosenwasser MP. The epidemiology of upper extremity fractures in the United States, 2009. *J Orthop Trauma*. 2015;29:242–244.
- Anakwe RE, Aitken SA, Cowie JG, et al. The epidemiology of fractures of the hand and the influence of social deprivation. *J Hand Surg Eur Vol*. 2011;36:62–65.
- Buchholz RW. Chapter 3. The epidemiology of fractures. *Rockwood and Green's Fractures in Adults*. Vol 1. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2009.
- van Onselen EB, Karim RB, Hage JJ, et al. Prevalence and distribution of hand fractures. *J Hand Surg Br*. 2003;28:491–495.
- Diaz-Garcia R, Waljee JF. Current management of metacarpal fractures. *Hand Clin*. 2013;29:507–518.
- Fricker R, Nuñez F. AO surgery reference: hand fractures. 2016. Accessed March 1, 2018. Available at <https://www2.aofoundation.org/>.
- Koç T, Ahmed J, Aleksyeyenko S. Buried Kirschner wires in hand trauma: do they reduce infection rates and is it worth the extra cost? *Eur J Plast Surg*. 2012;35:803–807.
- Cheng HS, Wong LY, Chiang LF, et al. Comparison of methods of skeletal fixation for severely injured digits. *Hand Surg*. 2004;9:63–69.
- Hsu LP, Schwartz EG, Kalainov DM, et al. Complications of K-wire fixation in procedures involving the hand and wrist. *J Hand Surg Am*. 2011;36:610–616.
- Hargreaves DG, Drew SJ, Eckersley R. Kirschner wire pin tract infection rates: a randomized controlled trial between percutaneous and buried wires. *J Hand Surg Br*. 2004;29:374–376.
- Das De S, Bae DS, Waters PM. Displaced humeral lateral condyle fractures in children: should we bury the pins? *J Pediatr Orthop*. 2012;32:573–578.
- Wormald JCR, Jain A, Lloyd-Hughes H, Gardiner S, et al. A systematic review of the influence of burying or not burying Kirschner wires on infection rates following fixation of upper extremity fractures. *J Plast Reconstr Aesthet Surg*. 2017; 70 (9): 1298–1301.
- Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42:377–381.
- Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J R Stat Soc Series B*. 1995;57(1):289–300.
- Bhangu A, Kolas AG, Pinkney T, et al. Surgical research collaboratives in the UK. *Lancet*. 2013;382:1091–1092.
- Tolkien Z, Potter S, Burr N, et al. Conservative management of mallet injuries: a national survey of current practice in the UK. *J Plast Reconstr Aesthet Surg*. 2017;70:901–907. doi: 10.1016/j.bjps.2017.04.009. [Epub ahead of print].
- Ridley TJ, Freking W, Erickson LO, et al. Incidence of treatment for infection of buried versus exposed Kirschner wires in phalangeal, metacarpal, and distal radial fractures. *J Hand Surg Eur Vol*. 2017;42:525–531. doi: 10.1016/j.jhbs.2017.03.040. [Epub ahead of print].
- van Leeuwen WF, van Hoorn BT, Chen N, et al. Kirschner wire pin site infection in hand and wrist fractures: incidence rate and risk factors. *J Hand Surg Eur Vol*. 2016;41:990–994.
- Botte MJ, Davis JL, Rose BA, et al. Complications of smooth pin fixation of fractures and dislocations in the hand and wrist. *Clin Orthop Relat Res*. 1992;194–201.
- Peduzzi P, Concato J, Kemper E, et al. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol*. 1996;49:1373–1379.
- Vittinghoff E, McCulloch CE. Relaxing the rule of ten events per variable in logistic and Cox regression. *Am J Epidemiol*. 2007;165:710–718.