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Review article

# Should Kirschner wires for fixation of lateral humeral condyle fractures in children be buried or left exposed? A systematic review

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ABSTRACT

*Background:* Displaced lateral humeral condyle fractures in children are usually treated with open reduction and internal fixation. When treated operatively with Kirschner wires, the bent cut near side wire ends are either buried in the subcutaneous tissue or are left exposed. It is believed that burying the wires allows them to remain in longer and hence facilitate better union. Leaving them exposed seems to necessitate earlier removal, especially to reduce the risk of wire tract infection. There is not a clear consensus in published literature whether subcutaneous wire burial is better or not.
*Patients and methods:* A systematic review of literature was performed using online database EMBASE, Pubmed, Medline, CINAHL and Cochrane database. The inclusion criteria comprised only those studies that compared lateral humeral condyle fracture fixation in children with wires buried subcutaneously versus those left exposed to skin.
*Results:* Of the four studies identified, three reported that it was safe to leave the wires exposed and that there was no statistically significant advantage of burying the wires with regards to risk of infection. However, our meta-analysis of the four studies demonstrated on forest plot charts that there is an increased risk of infection when the wires are left exposed (odds ratio 0.538 CI 0.437–0.639), but the overall complication rate was less in the group treated with exposed wires. Treatment with exposed wires was also cost effective when compared to treatment with buried wires.
*Discussion:* Our review concluded that despite a higher risk of superficial infections, exposed wires are safe and an economical option when fixing lateral humeral condyle fractures in children.
*Level of evidence:* II, systematic review.



## 1. Introduction

Fractures of lateral humeral condyle are common childhood injuries [1]. They are typically caused by a fall onto an extended arm with a varus directed force creating a 'pull off' avulsion fracture or valgus directed force leading to a 'push off' impaction fracture by the radially directed force against the lateral humeral condyle [1,2]. They can be missed at initial assessment, bear a risk of non-union and often require a longer period of immobilization than other distal humeral fractures [3]. Undisplaced fractures can be treated conservatively, however fractures with greater than 2 mm displacement need operative reduction and internal fixation [4]. The results of open reduction more than three weeks after the fracture are no better than those of no treatment, and may threaten the lateral condylar fragment by damaging its blood supply [5]. Open reduction and internal fixation with Kirschner wires (K-wires) is the most common technique of fixation practised in children, although the use of screws and biodegradable pins has also been described [4,6].

Even though K-wire is the most commonly used fixation device, there remains no clear consensus whether the wires should be buried subcutaneously or left exposed to skin. K-wires can be removed in a clinic setting if they are left exposed to skin and thus the patient can avoid a second surgery. This offers cost savings and logistical advantages over subcutaneously buried K-wires. However, concerns over exposed wires endure, as they may be associated with higher rate of complications especially infection [7].

Superficial K-wire site infections may be treated with a short course of antibiotics but deep infections can necessitate debridement and a long course of intravenous antibiotics. Reduction in situ time of exposed K-wires may reduce the risk of infection, but a

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Search History (9)

| # ▲ | Searches | Results |
|---|---|---|
| 1 | lateral humeral condyle.mp. | 123 |
| 2 | exp Kirschner wire/ or buried k wires.mp. | 5938 |
| 3 | Kirschner wire/ or exposed k wire.mp. | 5938 |
| 4 | exp Kirschner wire/ or unburied k wire.mp. | 5938 |
| 5 | fractures.mp. or exp fracture/ | 281690 |
| 6 | 1 and 5 | 113 |
| 7 | 3 or 4 | 5938 |
| 8 | 2 and 6 and 7 | 20 |
| 9 | limit 8 to (human and english language) | 15 |

**Fig. 1.** EMBASE search criteria.

**Table 1**
Eligibility for inclusion of clinical trials based on validated quality assessment tool for clinical research of Rangel et al. [9].

| Critical analysis of clinical research reporting by Rangel et al. | Ormsby et al. | Das De et al. | Chan et al. | Launay et al. |
|---|---|---|---|---|
| Baseline reporting criteria | | | | |
| (Description of participating surgeons/institutions | | | | |
| Can number of participating centers be determined? | Yes | Yes | Yes | Yes |
| Can practice type be determined? | Yes | Yes | Yes | Yes |
| Can number of surgeons be determined? | Yes | No | No | No |
| Can author's prior experience with procedure be determined? | No | No | No | No |
| Is timeline of when cases performed documented? | Yes | Yes | Yes | Yes |
| Description and definition of cases | | | | |
| Was population from which cases selected described? | Yes | Yes | Yes | Yes |
| Are diagnostic criteria clearly documented? | Yes | Yes | Yes | Yes |
| Are eligibility criteria clearly documented? | Yes | Yes | Yes | Yes |
| Description of the intervention | | | | |
| Is surgical technique adequately described? | Yes | Yes | Yes | Yes |
| Any attempt to standardize operative technique mentioned? | Yes | Yes | Yes | Yes |
| Any attempt to standardize perioperative technique mentioned? | Yes | Yes | Yes | Yes |
| Analysis of outcome data | | | | |
| Is mean and range of demographic data reported? | Yes | Yes | Yes | Yes |
| Are outcomes presented with appropriate measure of variability? | Yes | Yes | Yes | Yes |
| Are diagnostic methods for defining outcome described? | Yes | Yes | Yes | Yes |
| Do authors address whether there are missing data? | No | Yes | Yes | No |
| Is number and nature of complications addressed? | Yes | Yes | Yes | Yes |
| Satisfy the criteria | 13/16 | 13/16 | 14/16 | 13/16 |

Total number of criteria = 16.

shorter period of fixation may not provide enough time for a sound union [8]. The risk of infection is believed to be less by burying the K-wires subcutaneously and it also appears to create an advantageous milieu that allows longer in situ implantation until sound radiological union occurs.

Our primary objective of this systematic review was to evaluate the safety and efficacy of treating lateral humeral condyle fracture in children with exposed K-wires compared to buried K-wires.

## 2. Materials and methods

We conducted a systematic review of literature using the online database EMBASE, Medline, Pubmed, Cochrane database and CINAHL. The terms used for the EMBASE search are shown in Fig. 1, and this methodology was used to search other databases. The searches were carried out on April 4, 2017 and were not limited by year of publication. Studies available only in English literature and on humans were considered for review.

We included the clinical trials that compared subcutaneously buried K-wire to exposed K-wires in treatment for lateral humeral condyle fracture fixation in children. Eligibility for inclusion of clinical trials was individually assessed by the two authors (RR and AJD) based on validated quality assessment tool for clinical research of Rangel et al. [9] (Table 1) and any disagreements resolved with discussion.

We performed a meta-analysis using forest plots, odds ratio and confidence intervals to determine the safety and efficacy of overall complications between the exposed K-wires group and buried K-wires group.

## 3. Results

Thirty-eight studies were identified by our search strategy. All abstracts were reviewed and five were selected for a full paper review. One study was later excluded [10] as it was found to be a part of one of the included studies [11]. The remaining four studies [7,11–13] fulfilled the criteria and formed part of this study. They compared the two treatment methods and comprised 491 patients. The concise details of the four studies included are presented in Table 2.

### Summary of evidence

Studies [11–13] demonstrating safe and cost-efficient practice of fixation of lateral humeral condyle fractures in children with exposed K-wires compared with subcutaneously buried K-wires.

**Table 2**
Summary of included studies.

| Study | Study design | Population | Intervention/Comparator | Results | Complications |
|---|---|---|---|---|---|
| Chan et al., 2011 | Retrospective Cohort | Children with lateral humeral condyle fracture<br>*n* = 75, buried–42, unburied–33 | Open reduction and fixation with K-wires<br>Follow-up–8.4 months<br>Unburied–4 weeks, wire removal + 2 weeks in backslab after wire removal<br>Follow-up–5.6 months | No revision surgery. Buried wires-fixation with 2 wires, Divergence angle–$11^0$<br>Unburied wires – Fixed with 2 or 3 wires, Divergence angle–$39^0$<br>Cost savings per patient–$800–$1100 | Buried-lateral condyle overgrowth in 4 patients<br>Unburied wires<br>Pin tract hypergranulation–2 ($p = 0.11$)<br>Superficial pin tract infection–1 ($p = 0.26$)<br>Lateral condyle overgrowth–7 ($p = 0.08$) |
| | | Mean age–5.0 years, 47 boys, 28 girls | Buried–5 weeks of immobilisation | Wires left in situ<br>Buried–11.6 weeks<br>Unburied–4.4 weeks | |
| Ormsby et al., 2016 | Retrospective cohort | Children with lateral humeral condyle fracture<br>*n* = 124, buried–60, unburied 64 | Buried–2 percutaneous with arthrogram otherwise all open reduction and fixation<br>Unburied–Open reduction<br>Mean follow up–155 days<br>All buried wires removed in theatre under general anaesthetic | No incidence of non union. Strong association of skin erosion in buried group when treated early ($p = 0.07$)<br>Buried wire removal mean–45 days (30–58)<br>Unburied wire removal mean–29 days (11–43) | 3 needed revision surgery–1 buried, 2 unburied<br>Buried group<br>Skin erosion–14<br>Proven infection–9<br>Unburied group<br>Proven infection–8<br>Microbiologically proven infection<br>Buried vs. Unburied statistically not significant ($p = 0.972$) |
| | | Mean age–5.12<br>80 boys, 44 girls | Unburied wires removed in clinic | Cost saving per patient if unburied £1400 | |
| Das De et al. 2012 | Retrospective cohort | Lateral humeral condyle fractures<br>*n* = 235, buried–194, unburied–41 | Open reduction and fixation<br>Cast immobilisation<br>Buried–6 weeks<br>Unburied–5.5 weeks<br>Buried wires removed under general anaesthesia | Buried wire removal–6 weeks<br>Unburied wire removal–4 weeks | Superficial infection<br>Buried–6<br>Unburied–4, $p = 0.076$<br>Deep infection<br>Buried–1, Unburied–0<br>Union time > 8 weeks–2<br>Others–4<br>Buried<br>Pin migration–31<br>Pain from prominent pin–14<br>Superficial skin necrosis–2<br>Pin migration and revision–2<br>Union time > 8 weeks–4<br>Others–9 |
| | | Mean age buried-6.1, unburied 6.2<br>148 boys, 87 girls | Unburied wires removed in office without anaesthesia<br>Median follow up<br>Unburied–4 months, Buried–5 months | Average cost saving in unburied group per patient $3442 | |
| Launay F et al., 2004 | Retrospective cohort | Lateral humeral condyle fractures<br>*n* = 57, Buried–25, unburied–32 | Open reduction and fixation–52<br>Percutaneous fixation–5<br>Cast immobilisation–6.5 weeks | Average K-wire removal 5.9 weeks | Malunions-5<br>Lateral spur-42<br>Unburied complications<br>Superficial infection–8<br>Deep infection–1<br>Lateral spur–27 |
| | | Mean age–6.2 years<br>38 boys, 19 girls | Buried wires removed under general anaesthesia<br>Unburied wires removed in clinic with no anaesthesia | | Buried complications<br>Superficial infection–2<br>Lateral spur–15 |

Ormsby et al. [11] studied a retrospective cohort comparing subcutaneously buried versus exposed K-wires for fixation of paediatric lateral condyle elbow fractures to determine the difference in complication rate and costs associated with treatment. Their study included 124 patients, of which 60 had buried K-wires and 64 had exposed K-wires. The cohort comprised 80 boys and 44 girls with a mean age of 5.12 years. All fractures were closed. 122 were managed with open reduction and K-wire fixation and two were treated with closed reduction, arthrogram and percutaneous K-wiring. All patients were followed to radiological union and no non-union was observed. The mean duration of follow up was 155 days.

All patients with buried K-wires had a second surgical procedure after radiological union for removal of K-wires in an operation theatre under general anaesthetic. This occurred at a mean 45 days (range 30–58 days) from the initial procedure. Exposed K-wires patients had their K-wires removed in outpatient clinic at a mean 29 days (range 11–43 days) after surgery and their elbows were immobilised for a further 1–2 weeks in plaster cast until radiological union is observed.

Microbiologically proven infection occurred in 17 patients and of which two were deep infections. Eight infections were observed in the exposed K-wire group and 9 in buried K-wire group however there was no statistically significant difference in infection observed between the two groups ($p = 0.972$). This difference was calculated by the statistical probability analysis using a two-tailed homoscedastic student's t-test. A further four patients in exposed K-wire group were commenced on empirical antibiotics due to clinical K-wire site appearances but the antibiotics were discontinued once negative microbiology results were reported.

Of the 60 patients treated with buried K-wires, 14 developed overlying skin erosions from the K-wires and of which 6 had microbiology proven infection. Their study demonstrated strong association between very early surgery with buried K-wires (mean time to theatre 1.42 days) and overlying skin erosion as compared to those with buried K-wires (mean time to theatre mean 2.5 days) that did not erode skin ($p = 0.07$).

Three patients required revision surgery. One patient each in buried and exposed group had exploration and debridement due to deep infection. One patient in exposed group underwent a revision procedure due to early failure of fixation and re-displacement of fracture. All fractures united post revision surgery.

Das De et al. [12] studied a retrospective cohort of 235 children with displaced humeral condyle fractures treated with K-wires for cost effectiveness and complications. There were 148 boys and 87 girls with a mean age of 6.1 years. All fractures were treated with open reduction through lateral or postero-lateral approach and fixation with K-wires. Forty-one children (17.4%) were treated with exposed K-wires and 194 (82.6%) with buried K-wires. Elbow was immobilised in an above elbow cast in both groups. Exposed K-wires were removed in office setting without local anaesthesia and buried K-wires were removed under general anaesthesia in the surgical centre. The median time to K-wire removal was 4 weeks in exposed K-wire group compared to 6 weeks in buried K-wire group ($p < 0.05$). Fracture stability was examined under fluoroscopy in all patients at removal of K-wires and elbow was splinted for an additional 1 to 2 weeks if further immobilisation was thought necessary.

Dichotomous outcomes were compared using the Fisher exact test, continuous variables were analysed using the Wilcoxon sum rank test. Spearman correlation test was used to examine the relationship between and duration of pin placement. A $p$ value of $< 0.05$ was considered statistically significant.

The rate of superficial infection was 9.8% (4 patients) for exposed K-wire group as compared to 3.1% (6 patients) in buried K-wire group. The deep infection rate was 0.5% (1 patient) in K-wire buried group compared with none in the exposed group. Their four superficial infections in exposed K-wire group and six in buried group ($p = 0.076$) along with one deep infection in K-wire buried group and none in exposed K-wire group ($p = 1.00$) did not demonstrate statistically significant difference.

There were additional complications in the K-wire buried groups that included, K-wire migration through the skin in 31 (16%) patients. Fourteen of those migrated K-wires were removed in clinic and the remaining 17 were removed in operation theatre under general anaesthetic. Fourteen (7.2%) patients also reported pain and discomfort from prominent K-wire and additional surgery was performed on two (1%) patients to retrieve the internally migrated K-wires.

Chan et al. [13] compared safety and efficacy on a retrospective cohort of 75 children whose lateral humeral condyle fractures were treated with exposed or buried K-wires. There were 47 boys and 28 girls with a mean age of 5.0 years. All children were treated with open reduction by lateral or postero-lateral approach and fracture fixation with K-wires. Forty-two children had buried K-wires and 33 had exposed K-wires. They were immobilised in an above elbow back slab post-operatively, which was changed to a full cast at 1 week when X-rays and wound inspection was carried out. Patients treated with exposed K-wires were then followed up at 4 weeks post surgery for X-rays and K-wire removal and a removable back slab was applied for another 2 weeks. Patients with buried wires were followed up at 5 weeks post surgery and a further immobilisation of 2 weeks was at the discretion of treating surgeon.

Patients with buried K-wires were usually treated with 2 wires at a divergence angle of $11^0$, while the exposed K-wire group were treated with 2 or 3 K-wires with a larger divergence angle of $39^0$. All fractures progressed to radiological union with no incidence of non-union. Buried K-wires were left in situ for a mean 11.6 weeks as compared to mean 5.2 weeks for the exposed K-wires ($p < 0.01$). Statistical analysis was performed with SPSS 17 for windows (SPSS Inc, Chicago, IL, USA). Categorical data were compared with Pearson's chi-square test. Continuous data were compared with Mann-Whitney test for nonparametric data and independent t test for parametric data. Statistical significance was defined as $p < 0.05$.

Deep infection or fracture displacement was not observed in either group. No infection was observed in the buried K-wires group. In the exposed K-wire group, one patient developed superficial infection ($p = 0.26$) that was treated with a week of oral antibiotic and two developed hypergranulation ($p = 0.11$) at the pin tracts that was treated with topical silver nitrate. Greater radiological lateral condyle overgrowth was noted in exposed K-wire group over buried K-wire group but this was neither clinically apparent nor statistically significant ($p = 0.8$).

### 3.1. Study showing increased risk of infection with exposed K-wires for treatment of lateral humeral condyle fractures in children compared to buried K-wires

Launay et al. [7] conducted a retrospective study to investigate whether minimally displaced lateral humeral condyle fractures should be treated surgically and compared different techniques of operative management. For our review we reviewed results of 57 patients with displaced fracture that were treated operatively and fractures stabilised with K-wires. There were 38 boys and 19 girls with a mean age of 6.2 years. 52 patients had open reduction and fixation and 5 had percutaneous fixation. Thirty-two patients had exposed K-wires and 25 had K-wires buried. All patients received long arm (above elbow) immobilisation for an average 6.5 weeks post-operatively. Exposed K-wires were removed in an outpatient clinic without anaesthesia and buried K-wires were removed in operating room under general anaesthesia. The average K-wire removal was 5.9 weeks after surgery.

Eleven infections were observed, of which 10 were superficial infections and one deep infection. Of the 11 infections, 8 superficial infections and one deep infection were observed in the exposed K-wires group (9/32, 28.1%). Infection necessitated early wire removal in two patients and led to loss of fracture reduction in one patient. Two superficial infections were observed in the buried K-wires group (2/25, 8%). All (10) superficial infections resolved with oral antibiotics, local wound care and removal of K-wires (in two patients). One deep infection needed wire removal, irrigation, debridement and prolonged antibiotic therapy.

Five mal-unions occurred but none required revision surgery. There were no non-unions. Lateral spur formation occurred in 42 patients and was observed in 60% of buried K-wires group and in 84.4% exposed K-wires group.

Statistical analysis was done using Pearson chi-square test and Fischer exact test. Differences with a $p$ value of 0.05 or less were considered statistically significant.

### 3.2. Complications in-group treated with buried K-wires versus exposed K-wires

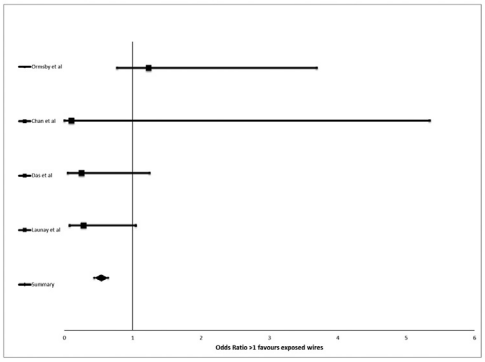
The complications of the above studies are summarized in Table 2. They include infection, skin necrosis, K-wire protrusion, pin tract hyper-granulation, lateral humeral condyle overgrowth and revision surgery.

Three of the four studies [11–13] reported no statistical difference in the rate of infection between the exposed K-wires and buried K-wires groups. Our meta-analysis on forest plot (Table 3) exhibited that all individual studies had 95% confidence intervals

**Table 3**
Forest plot of odds ratios and 95% confidence intervals for an outcome of infection with buried versus exposed wires.

| Author | Number | Buried | Exposed | Infection buried | Infection exposed | Odds ratio | CI low | CI high | Weight |
|---|---|---|---|---|---|---|---|---|---|
| Ormsby | 124 | 60 | 64 | 9 | 8 | 1.2332 | 0.7741 | 3.6933 | 30.96 |
| Chan | 75 | 42 | 33 | 0 | 1 | 0.103 | 0.002 | 5.3431 | 18.48 |
| Das | 235 | 194 | 41 | 7 | 4 | 0.2536 | 0.0516 | 1.2455 | 34.68 |
| Launay | 57 | 25 | 32 | 2 | 9 | 0.281 | 0.0755 | 1.0455 | 14.04 |
| Summary | 491 | 321 | 170 | 18 | 22 | 0.538 | 0.437 | 0.639 | 98.16 |

**Forest plot of odds ratios and 95% confidence intervals for an outcome of infection with buried vs exposed wires.**




(CI-Confidence interval)

vs = versus

crossing 1, indicating the observation not to be statistically significant. However, combined number exhibited statistical significance, as the error was reduced with pooled numbers suggesting infection rate was significant in the exposed K-wires group compared with buried K-wires group. Skin necrosis and skin protrusion was a complication seen only in buried K-wires group. There was none recorded in exposed K-wire group. The meta-analysis with forest plot (Table 4) demonstrated lower overall complication rate in exposed K-wires group as compared to buried K-wires group.

### 3.3. Cost effectiveness

Three [11–13] of the four studies showed significant cost savings in exposed K-wires group as compared to buried K-wires group primarily from need of a second operation for wire removal under general anaesthetic in the latter. Ormsby et al. [11] calculated a potential cost saving of £1400 per patient while considering factors such as surgical theatre time costs and uncomplicated ward bed costs, Das De et al. [12] a cost saving of US $3442 per patient and Chan et al. [13] a cost saving of US $800–$1100 per patient.

## 4. Discussion

The decision to bury the K-wires or to leave them exposed is mainly dependent on surgeon preference. Studies treating hand and wrist injuries suggest exposed wires are associated with a higher rate of infection when compared to buried wires [14] and form basis of using buried wires. In our review three [11–13] of the four studies found no significant increase in the rate of infection in patients treated with exposed K-wires as compared with patients treated with buried K-wires.

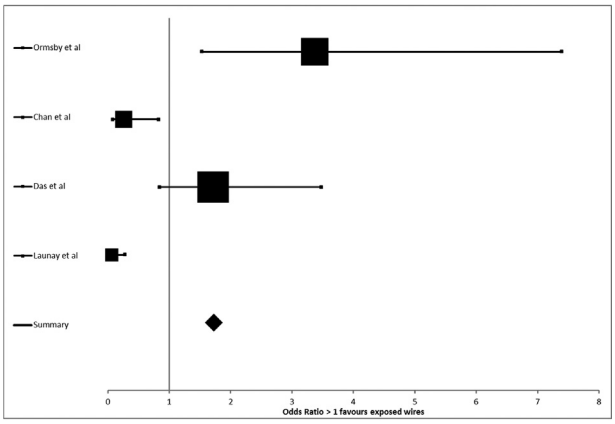
Das De et al. [12] reported no significant difference in the infection rates between exposed and buried K-wire groups. Chan et al. [13] reported a low rate of one pin site infection in exposed K-wire group and none in buried group demonstrating no statistical difference ($p = 0.26$). Ormsby et al. [11] used microbiology testing to confirm infection. Among their 17 infections, nine infections (including one deep infection) occurred in buried group and eight (including one deep infection) in the exposed group yet again did not show a statistically significant difference ($p = 0.972$). Their study included four patients who were empirically treated for infection however the antibiotics were discontinued after negative microbiology results. Hence, confirmation of infection by microbiology testing is an important factor in documenting infection. Launay et al. [7] reported a higher rate of infection in patients treated with exposed K-wires. However, their publication did not specify how infection was confirmed. Subjective decision made solely on the appearance of pin sites could cause false positive decisions and lead to increased prescription of empirical antibiotics and could potentially lower the threshold of reporting infection. Even though our meta-analysis showed increased rate of infection in exposed K-wire group, it may not reflect a true picture if the infections have been documented without a microbiology test.

Our review also exhibited that skin necrosis and pin migration through skin was a complication associated with buried K-wires. Das De et al. [12] reported two patients with skin necrosis in buried group and none in exposed group. They also reported 31 cases of pins migrated through the skin in the buried group. Ormsby et al. [11] reported 14 (23%) cases of skin erosion and wire protrusion. They also found a strong association of skin necrosis and wire erosion among those patients who were treated very early after injury (within 24–36 hours). This could be from the wires that were believed to be well buried at the time of surgery may have become prominent with subsidence of soft tissue swelling, causing them push through and erode the overlying skin. Also, skin necrosis or wire protrusion occurrence leaves wire burial ineffective with damage to skin. An alternate solution may be to use biodegradable implants that could be cut flush to the condyle thus removing pressure on skin and eliminating the need for implant removal. A study by Takada et al. [15] showed no infections or skin erosions with use

**Table 4**
Forest plot of complications in buried versus exposed wires.

| Author | Number | Buried | Exposed | Complications buried | Complications exposed | Odds ratio | CI low | CI high | Weight |
|---|---|---|---|---|---|---|---|---|---|
| Ormsby et al. | 124 | 60 | 64 | 24 | 10 | 3.37 | 1.5351 | 7.3983 | 30.96 |
| Chan et al. | 75 | 42 | 33 | 4 | 10 | 0.2591 | 0.081 | 0.8285 | 18.48 |
| Das et al. | 235 | 194 | 41 | 71 | 10 | 1.7129 | 0.8443 | 3.4747 | 34.68 |
| Launay et al. | 57 | 25 | 32 | 17 | 36 | 0.0631 | 0.0141 | 0.2828 | 14.04 |
| Summary | 481 | 321 | 170 | 116 | 66 | 1.726 | 1.625 | 1.827 | 98.16 |

**Forest plot 2: Odds ratio of complications in buried vs exposed wires.**




(CI-Confidence interval)

vs = versus

of biodegradable pins. However foreign body reaction and infections with biodegradable implants have been reported by Savvidis et al. [16]. Biodegradable implants can be dearer and hence their cost effectiveness would indicate further assessment.

Buried K-wires gain a theoretical advantage that they can be left in situ for a longer period until radiological union occurs while K-wires in the exposed group need to be removed earlier to reduce risk of infection. Three of the studies [11–13] we reviewed showed that the buried K-wires were indeed left longer than in the exposed K-wire group. Confirmation of radiological union was the key before buried K-wires were removed. On the other hand, exposed K-wires were removed between 4–6 weeks and elbows immobilised in a back slab if needed. Even though the exposed K-wires were removed earlier and irrespective of radiological union, no loss of reduction or need for reoperation was observed from early wire removal. This shows that there is no significant advantage of buried K-wires over exposed K-wires as far as fracture union is concerned. Boz et al. [17] removed wires at 4 weeks and found it efficient to achieve satisfactory functional results.

All the studies reported removal of exposed K-wires in an outpatient clinic or office setting without anaesthesia while buried K-wires were removed in theatre under general anaesthesia. Removing the K-wire in clinic setting under simple analgesia is reported acceptable and effective [18,19]. Removal of buried K-wires required a second operation under general anaesthesia in theatre. This second procedure could increase the anxiety of patients and parents [13] with increased cost of treatment [11–13].

Our study has some limitations. First, only four studies could be identified. However, we performed a thorough electronic database search for randomised studies to minimize the possibility of publication bias. Secondly, all the studies were retrospective cohort studies and therefore bear inherent bias. Thirdly, the differences in study design and outcomes measures make it difficult to do direct comparisons thereby narrowing the scope for extensive meta-analysis. Fourthly, the difference in outcome variables could affect the interpretation along with the differences caused by observer's outcome measure. However, different outcome measures used by various authors could still demonstrate improvement and differences in outcome between the treatment modalities.

## 5. Conclusion

Our systematic review found that treatment of lateral humeral condyle fracture fixation in children with exposed K-wires is safe and effective alternative to buried K-wires. The superficial infection rate by using exposed K-wires was higher to that treated with buried K-wires. Greater overall complications including skin necrosis and wire protrusion through the skin occurred with buried K-wires and could be minimised or avoided by leaving K-wires exposed to skin. Our review also showed significant cost savings with use of exposed K-wires. Finally, we suggest need for well-designed and adequately powered randomised controlled trial to establish these findings.

## Disclosure of interest

The authors declare that they have no competing interest.

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## Contribution of authors

Roshan Raghavan: concept, database search and manuscript writing.

Alistair Jones: statistics and manuscript editing.

Amitabh J. Dwyer: analysis, manuscript writing and editing.

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