Pin-site Care And Innovations In Practice: The Royal Stoke University Hospital Experience.

A McBride[1], P J Ogrodnik[2]

[1] Limb Reconstruction Clinical Nurse Specialist, Royal Stoke University Hospital, University Hospitals of North Midlands Trust, Staffordshire, UK

[2] Professor of Medical Devices Design, Institute of Science and Technology in Medicine, Keele University, Staffordshire, UK

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Abstract

This paper presents the Royal Stoke University Hospital pin-site care protocol. It has evolved during 25 years of fracture management research at the centre and has been developed in accordance with the RCN Consensus Guidelines on Pin-Site Care. However, it contains some innovative adjuncts that could minimise the incidence of pin-site infections requiring medicinal intervention. Scope for research on dressing type and cleansing solutions still remains. However, this article presents the importance of patient education and dressing compression in the prevention of irritation around the pin-site, thus reducing the risk of developing any infection.

1. Introduction

When a patient is treated with an external fixator the main body of the fixator has to be physically connected to the bone. This is achieved using two methods: the first is the fine k-wire (or Kirschner wire); the second is the half-pin.

The k-wire is most commonly used with Illizarov frame fixation systems[1] and their recent embodiments[2,3] (illustrated in Figure 1). Made from 316LVM stainless steel and usually less that 2mm in diameter (1.8 mm and 1.5 mm being common place) it passes through the bone and communicates with opposite sides of the frame creating a bilateral fixation. Therefore, there are two wounds per wire. Under tension (often about 1kN) the wire is fixed in place on the fixator body with locking clamps. The wires are commonly inserted in pairs creating a cross formation; this produces a mechanical fixing that does not rely on internal friction between the bone and the wire. A single cross-wire combination will, therefore, create 4 skin piercings.

Half-pins are most commonly used with mono-lateral external fixators[4,5]. A threaded portion creates an anchor with the bone; a smooth shank enables location with the fixator (as illustrated in Figure 2). Normally, the pins are made from 316L or 316LVM stainless steel and can be 3mm, 5mm or 6mm in diameter. They provide mono-lateral fixation and hence one wound is produced per pin.

Frame systems were developed by Illizarov and are often called Illizarov frames[1]. More complex embodiments have evolved such as the Taylor Spatial Frame[2] and Hexapod[3]. A common frame configuration can have 32 wounds created by 8 k-wire pairs. Modern frame systems, called hybrid systems, can have a combination of k-wires and half-pins. This means they could have a combination of 4 wires and 3 half-pins (or 11 skin piercings). Mono-lateral fixators tend to use half-pins in groups of 3 at each end [4,5] creating 6 individual skin piercings.

It is common practice to call these piercings, or wounds, as "*pin-sites*". This paper will follow this convention from now on.

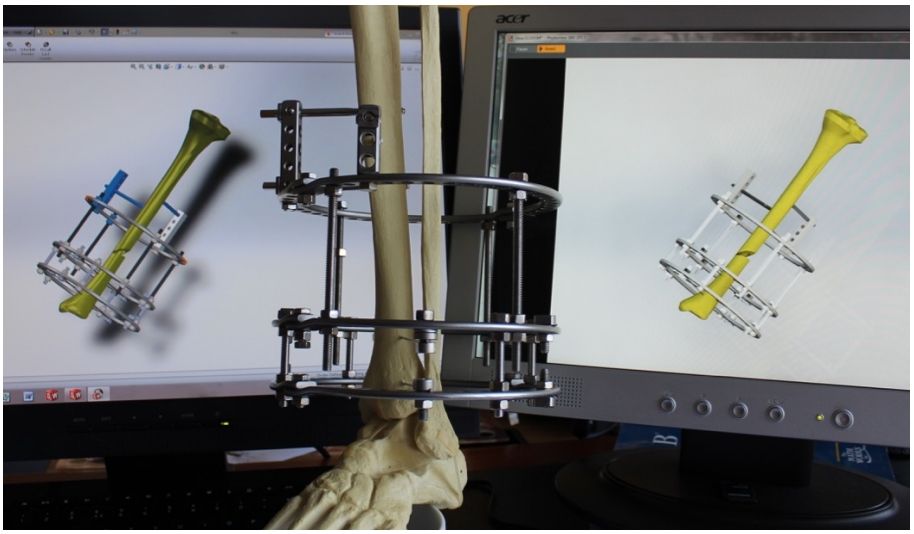

Fig 1 - A Typical Hybrid Illizarov Frame Fixator

Fig 2 – An Illustration of the Half-Pin Providing Mono-Lateral Location

Irrespective of which fixation device has been used it has to remain in place during the whole treatment period. For tibial fractures this could be up to 24 weeks, and for some reconstruction surgery it could be much longer. The pin-sites, therefore, are open to: the atmosphere, the environment, and to bacteria for the whole duration. Pin-site infection incidence is reported to be about 12%[6]. Out of these some 4% can increase in severity to osteomyelitis[6]. Hence pin-site care designed to avoid irritation, inflammation or infection is of paramount importance.

Pin-site infections have been categorised by various groups, these are summarised in Table 1.

Table 1 – Pin-site infection categories (adapted from Kazmers *et al.*[6])

Ward[7]	Saleh and Scott[8]	Checketts *et al.*[9]	Dahl *et al.*[10]	McBride[11] and RCN[12]
Redeemable with care				
Minor—Prolonged drainage, crusting, swelling, and erythema. Considered benign.	Grade 0—No problems.		Grade 0—Normal. Treat with weekly pin-site care.	THE CALM PIN-SITE-no redness, no exudate, no pain, looks just like an ear piercing. Weekly pin-site care.
	Grade 1—Responds to local treatment, increased cleaning, and massage		Grade 1—Inflamed. Daily pin-site care.	THE IRRITATED PIN-SITE-redness, painful, sometimes itchy and oozing exudate but NO pus. Daily pin-site care.
		Grade 1—Slight erythema, little discharge. Treat with improved local pin-site care		

	Grade 2—Responds to oral antibiotics	Grade 2—Erythema, discharge, pain, warmth. Treat with improved local -site care and oral antibiotics	Grade 2—Serous drainage. Antibiotics.	THE INFECTED PIN-SITE-redness, painful, oozing pus. Antibiotics and daily pin-site care.
	Grade 3—Responds to intravenous antibiotics or pin releases	Grade 3—As per grade 2, but no improvement with oral antibiotics. Pins/ex fix can be continued.	Grade 3—Purulent discharge. Antibiotics.	
Catastrophic				
		Grade 4—Severe soft tissue infection involving several pins ± pin loosening. Ex fix must be discontinued.		
Major—Resolution requires removal of affected pins..	Grade 4—Responds to removal of the pin.	Grade 5—As per grade 4, but with bone involvement visible on radiographs. Ex fix must be discontinued.	4—Osteolysis. Pin removal.	
	Grade 5—Responds to local surgical curettage.	Grade 6—Major infection occurring after ex fix removal. Treatment requires curettage of pin track.	Grade 5—Ring sequestrum. Debridement.	

Table 1 illustrates that there is little in common, or any agreement, on the definition of a pin-site infection. However, there can be little doubt that any pin-site that has not progressed to "catastrophic" is potentially redeemable. Anything that has achieved catastrophic status means a significant change in treatment methodology; this should be avoided. It is to this extent that this study has adopted the grading scheme taken from the RCN guidelines[12] (due to be updated in 2018) and adapted by McBride[11]. The aim is to emphasise that all pin-sites should not be allowed to progress beyond the "infected pin-site" classification, but to maintain a "calm pin-site" classification.

Figure 3 illustrates a typical mono-lateral external fixator whose pin-site would be classified as a "calm pin-site" (Minor or Grade 0 in the other grading schemes). Figure 4 illustrates an irritated pin-site, and Figure 5 a pin-site that

has become infected. The transition between the first two classifications is the onset of redness around the site associated with some irritation. Sequestration of pus from the pin-site indicates an infected pin-site (Figure 5). Often the transition from irritated to infected is associated with the patient complaining of painful pin-sites.

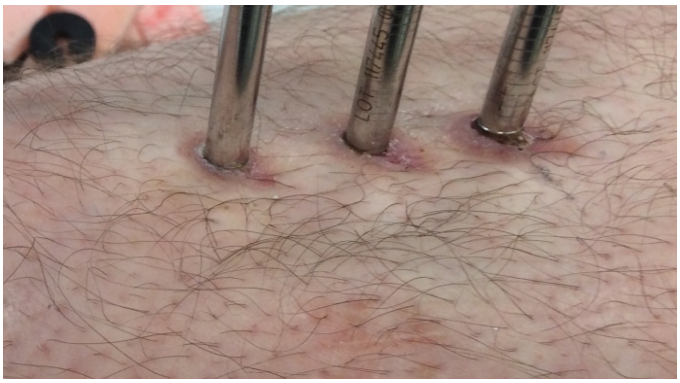

Fig. 3 – An example of a “calm pin-site”

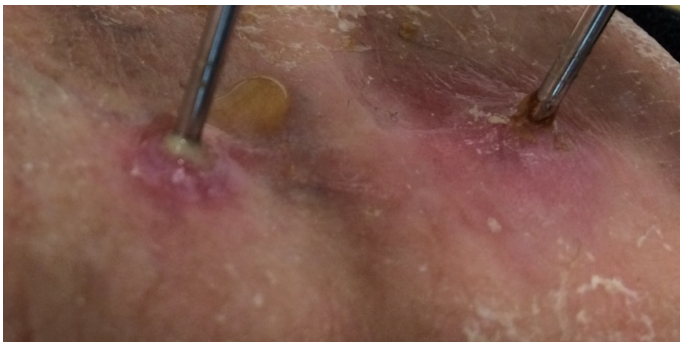

Fig. 4 – An example of an “irritated pin-site” (erythema and clear exudate)

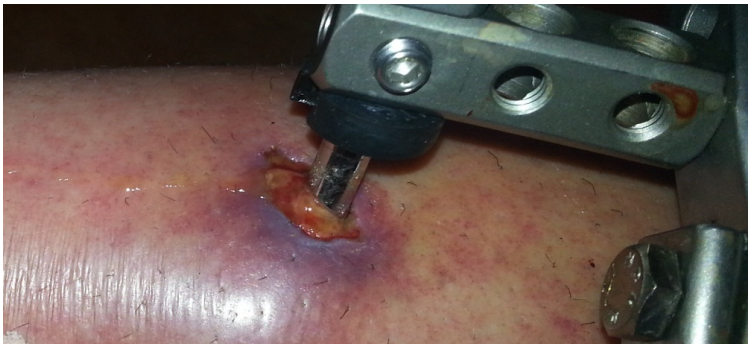

Fig. 5 – An example of an “infected pin-site” (erythema and evidence of pus)

2. The Royal Stoke Pin-Site Care Pathway

The standard of care in pin-site treatment at the Royal Stoke Hospital, with the aid of the RCN Consensus guidelines[12], has reduced the incidence of pin-site

infection rates dramatically. However, one of the most important factors in achieving this is patient education.

The following is a précis of the protocol developed at the Royal Stoke University Hospital and has been in use for the past seven years.

Peri-operative

Apply individual *Charnley Sponges* soaked in *chlorhexidine* to each pin-site. Each sponge is compressed using a retainer.

Post-operative (day 8-15 – or at the first outpatient appointment)

The Charnley sponges are removed.

The pin-sites are cleaned using an aseptic technique (*normasol* and sterile gauze). A double layer, foam dressing is applied to each pin-site and compressed using a retainer.

Patients, their relatives, and carers are taught how to successfully perform pin-site care. They are taught how to clean and redress their pin-sites (following the RCN Pin-Site Consensus Guidelines [12]). We suggest that they are cleaned and redressed weekly. We further recommend the use of Hydrex solution 0.5% as the cleansing agent. At each dressing change it is important that the retainers are either replaced with new or thoroughly washed and disinfected.

All patients are taught the three states of a pin-site (Figures 3-5). They are also taught what to do if they develop irritated or infected pin-sites (Figures 4 & 5): see *telephone triage* later.

Until the fixator is removed

Patients are informed to keep the limb dry. No bathing is allowed. Showering is permitted, prior to dressing change and with dressings in place, once a week only.

All patients are seen in routine outpatients' clinics every four to six weeks; this is part of their normal treatment programme.

The Royal Stoke run Nurse-Led clinics for patients with complications. For example those with: pin-site infection, over-granulation, and those who cannot manage their own pin-site care.

The Royal Stoke operates a telephone triage system. The triage runs Monday to Friday during normal hours. Patients can obtain immediate advice if a complication or a concern arises. All orthopaedic outpatient nursing staff have been trained to follow a clinical pathway devised at the Royal Stoke and can give advice. If deemed necessary, the patient may be seen within 24 hours.

A broad-spectrum antibiotic (normally Flucloxacillin) is only prescribed if a pin-site has progressed to an infected state (Figure 5). If a pin-site infection develops patients are advised about the potential for cross-contamination. We suggest that the infected pin-site is always the last to be cleaned and the retainer must not be used on another pin-site. Pin-site care is elevated to daily until the infection subsides.

Any over-granulation around a pin-site is treated with silver nitrate applied using a cutaneous stick. The pin-site is allowed to dry (about 5 minutes) and a new dressing is reapplied with a retainer.

Fixation removal

Normally, the fixation is removed using aseptic technique. This is performed within the outpatient setting and without the need for general anaesthesia. However, some patients may have been treated with olive wires, which require an operation to remove the fixation.

The pin-sites are prepped and dressed with sterile gauze (sutures are not required) and protected with a wool and crepe bandage.

Patients are also informed to keep their limb dry for a minimum of 3 days.

Depending on the initial procedure, patients are informed to partial weight bear, with crutches, until seen two-weeks post fixation removal.

After 3 days the bandage is removed at home. If the pin-sites are dry, patients are allowed to bathe or shower and re-dressing is not required. If the pin-sites are still moist, patients are allowed to shower only and redress using sterile dressings.

2 weeks post fixation removal

The pin-sites are checked. Normally all pin-sites are healed at this stage.

3. Compression Obtained Using a Dressing Retainer

3.1 Introduction to compression and pressure

The RCN Consensus Guidelines[12] stipulate that compression is required in order for the dressing to remain in place for as long as possible. However, the amount of compression required and the method of by which it is created is not specified, but the use of a retainer is recommended.

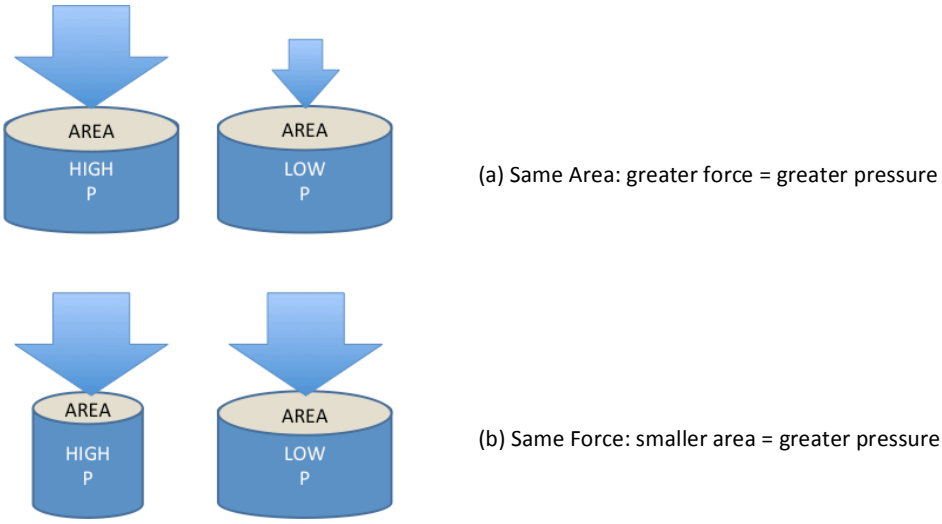

Fig. 6 – Force and Area and their respective effect on applied pressure.

Pressure is the ratio of force to the area[13] over which it acts:

$$p = F/A \qquad (1)$$

Its units are Newtons/square metre (N/m^2), or Pascals (Pa). However, in clinical practice it is more common to use its equivalent in height of mercury (mmHg). The commonly accepted conversion is 1000 N/m^2 (1kPa) = 7.5 mmHg[13].

The maximum compressive force is limited by the grip of the retainer on the wire or pin (Figure 7). This maximum compressive force we call the *retainer force*. Without the use of an adhesive, local adhesion, or mechanical fastening, friction between the wire/pin and the retainer limits the maximum compressive force a retainer can produce. Friction depends on the material combination and the cleanliness of the surfaces, but one may assume that an average coefficient of friction is 1/3[13]. Hence the maximum retainer force is about one third of its *clamping force.* The clamping force (Figure 7) produced is a combination of the stiffness of the retainer (its design and material) and the amount the clip deforms when placed over the wire (in effect the difference between pin and hole diameters). There is some local deformation of the material, but for the benefit of brevity we assume this is negligible.

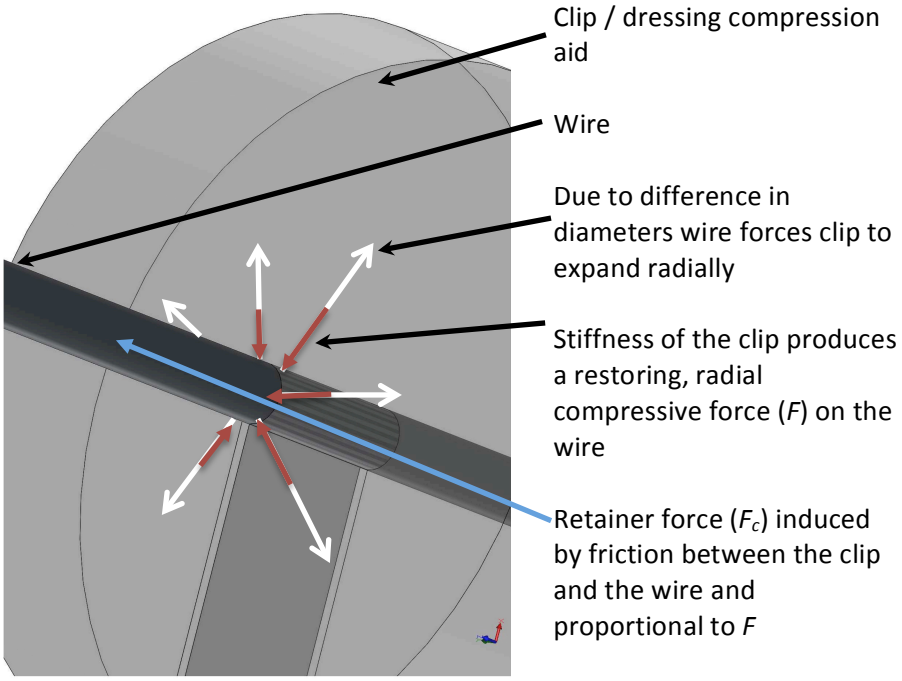

Fig. 7 - Diagrammatic representation of retainer force induced by forced expansion due to the difference in diameters

It is the retainer force that allows compression to be maintained. The effective area over which this force acts produces pressure on the soft tissues. The dressing itself can alter the area over which the force is applied. But, the dressings tend to be flexible and easily deformable; hence it is possible to assume that the area the force is distributed over is the clip area (A_c). Therefore the maximum pressure induced is:

$$p_{max} = F_c / A_c \text{ x } 0.0075 \quad \text{mmHg} \qquad (2)$$

Where A_c is in mm^2. However, to determine p_{max}, F_c must be known. Furthermore, A_c is the area that contacts with the dressing, not the overall size of the clip itself. Hence, a simple flat, round surface would have an area of :

$$A_c = \pi r^2 \qquad (3)$$

A flat rectangular clip (of breadth b and width w) would have an area of:

$$A_c = bw \qquad (4)$$

However a hollow bung would have an area of :

$$A_c = \pi(t^2 - rt) \qquad (5)$$

where *r* is the outer radius and *t* is the wall thickness of the bung.

3.2 Evaluation of two retainer designs

Two forms of dressing retainer were tested. The first (Figure 8a) is a commercially available "bung" type; the second is a new "removable clip" type (Figure 8b). The point of this initial investigation was to: i) examine their respective advantages and disadvantages, and ii) determine their respective retainer forces. The information would be useful to inform orthopaedic nurses on the criterion one should use to select a suitable dressing compression aid.

(a) Bung type (b) clip type
Fig. 8 – Dressing compression aids tested.

Retainer force is easily deduced by experiment. Two methods may be employed. The first is to measure the force required to pull a retainer from stationary. This produces a standard stick-slip type profile[13], as illustrated in Figure 8 (note: coefficient of friction in sliding is lower[13]). Retainer force is the peak force obtained, as illustrated. Whilst this produces a maximum force we believe this does not represent the retainer in use.

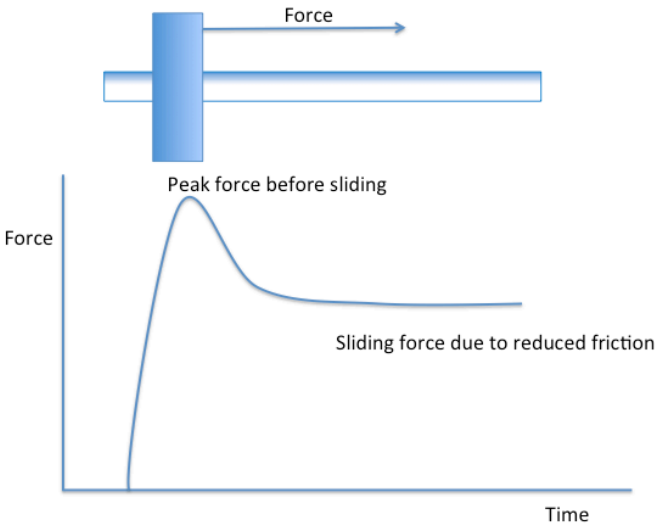

Fig. 9: Diagrammatic representation of sliding friction using a "pull" test.

We propose that the preferable method is to compress a calibrated spring. As the spring is compressed it produces a restoring force (analogous to the soft tissues and the dressing). When released the retainer / spring combination will settle to a steady-state position (as is observed *in-vivo*). However the spring must not be too stiff; this would induce inertia effects and make the measurement of compression difficult. Empirically, we found that a close-coiled helical spring with a stiffness of 630N/m with an ability to allow 10 mm compression provided a suitable soft-tissue / dressing analogue. The internal diameter of the spring should be large enough to surround the wire or bone-screw.

Figure 10 diagrammatically represents the experimental procedure. A frame fixator construct was built and the wires were tensioned as per normal practice. The wire was passed through a central spar such that an orthogonal wire enabled the spring to communicate with a flat surface. A spring of 630 N/m had been placed over one wire before tensioning, the free length of the spring was noted.

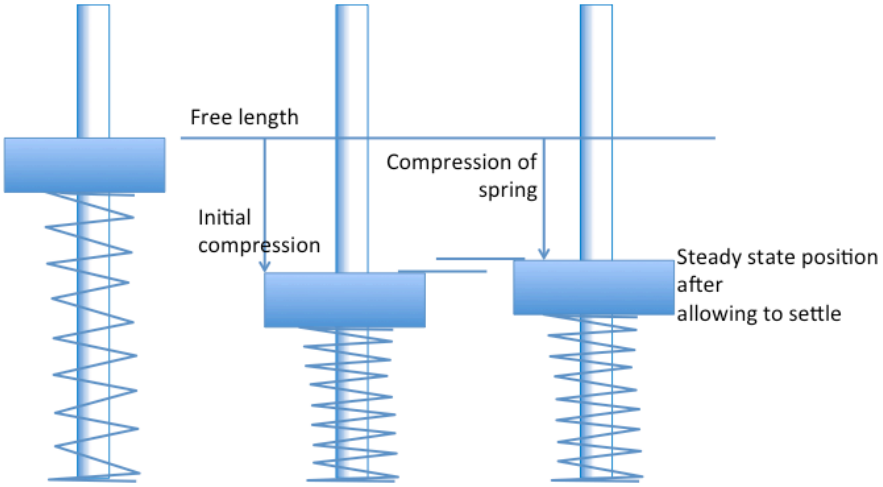

Figure 10 – Diagrammatic representation of experimental set-up to test grip force.

Bung procedure

A "bung" type retainer, as described in the RCN guidelines and illustrated in Figure 8(a), was placed over the wire prior to wire tensioning. Once tensioned and locked the bung was pushed against the spring and released. The whole frame was allowed to rest for 5 minutes to allow for the spring / retainer construct to settle to its steady state position. The compressed length of the spring was measured using a digital caliper. The compression of the spring was determined by subtracting the free length from the compressed length. The retainer force may then be determined from[13]:

$F_c = kx$

= 630 x compression (in m) (6)

This process was repeated for several similar bungs and several times, but to do so the wire-frame construct had to be dismantled and rebuilt for each new bung.

Clip procedure

A similar procedure was used for the clip type retainer (Figure 8(b)), but in this case the clip could be removed and attached without the need for dismantling of the wire-frame construct. Again the process was repeated for several similar clips and several times for each clip.

4. **Presentation and Discussion of Results**

Table 2 – Presentation of results

	Bung Type	Clip Type
Fixation	1.8mm k-wire	1.8mm k-wire
Retainer force (*Fc*)	5.04 N	2.52 N
Effective Area (*Ac*)	314 mm^2 (solid face) 163 mm^2(annulus)	380 mm^2
Contact Pressure (*p*)	16 kPa (solid face) 121 mmHg 31 kPa (annulus) 235 mmHg	6.6 kPa 50 mmHg
Advantages	Soft material Higher clip force Readily available from a variety of sources Clip deforms to irregular surface	Can be applied after operation outside of sterile field Can be removed, washed, and reapplied as required. Clip is clear allowing patient to see dressing around pin-site. Clips may be added, easily, to create higher compression (if required) Clip deforms, moderately, to irregular surface Lower contact pressure. Patient feedback very supportive Larger contact area
Disadvantages	Must be put on in the operating theatre Needs to be supplied sterile to be used in sterile field	Lower clip force Clip needs to be specific to size of wire / pin

	Cannot be removed for cleaning without destruction. Bung central aperture can store exudate and detritus. Bung is opaque; pin-site/dressing obscured. Higher contact pressure.	

Table 2 illustrates a comparison between 2 comparable dressing clips. The first column presents the results for the "bung" type retainer; the second for the "clip" design. The clip produced the lower retainer force. This force acted over an area of 380mm^2 (a 22 mm diameter washer), hence producing a pressure of 50 mmHg. The bung produced the higher force and acted over a smaller area (as it is an effective annulus). The annulus the contact pressure would be 235 mmHg. Turning it over and using the bung "face down" would reduce contact pressure to 121mmHg; this also removes the issue of the bung aperture being invisible to the naked eye.

A recent examination of pressure sores stated that using a limit of 32mmHg as a limiting pressure is too coarse[14]. There is sufficient evidence to suggest that the capillary pressure does not limit blood flow, but higher pressures can be sustained[14] due to the supporting soft tissues. A much-cited value of pressure related to the incidence of pressure sores is a maintained pressure exceeding 9.3 kPa (70.4 mmHg)[15] for more than 2-3 hours.

Seiler and Stahelin[16] suggest that pressures greater than 17kPa (129 mmHg) causes significant changes in oxygen tension, especially around bony sites. Equally recent studies on rat models[17] suggest that a long-term contact pressure below a value of 9kPa (67mmHg) does not predicate tissue damage.

It is, therefore advisable to have a clip that cannot exceed a sustained pressure of 9kPa. Tabl2 illustrates that the pressure created by the clip type device did not exceed this threshold value, but that of the bung type device did. There is, therefore, a risk of inducing pressure necrosis using a bung type dressing retainer if it is compressed excessively.

4.1 Review of Royal Stoke Pathway

Importantly the patients report that the foam dressing is particularly comfortable, especially when retained with the new clip.

The introduction of the telephone triage and nurse led service has resulted in a reduction in the number of in-patient admissions with complications.

Patient education together with the invention of the new compression clip has dramatically reduced the number of complications such as:

- Pin-site infections requiring treatment with antibiotics,
- Admissions to hospital with cellulitis due to severe pin-site infection,
- Premature removal of the external fixation and application of a plaster of Paris cast,
- Modification of primary treatment pathway (external fixator change) due to severe pin-site problems,
- Incidence of osteomyelitis (which can lead to amputation).

5. Conclusions

We have examined the role of pin-site care to avoid pin-site infections associated with the use of external fixation systems. We have presented a pin-site care protocol and have highlighted the need for compression of dressings around the pin-site.

Fig. 11 – New clip design for 1.8mm wire.

The importance of good compression around the pin-site is imperative in the prevention of irritation of the skin surrounding it. Thus holding the skin firmly will help in the prevention of this. Through research at Royal Stoke Hospital, the Metaclip has been developed for the thin wires (Figure 11). The Metaclip is an advanced design of one that was designed over 6 years ago.

As a consequence of our work to develop the care pathway we can also state that:

- The Royal Stoke Pin-Site Care Pathway has improved patient experience, patient outcomes, and quality of care.

- Dressing retainers should be designed such that the induced compression pressure does not exceed 9kPa (67mmHg).

- Dressing retainers should be tested to ensure that this limit is not exceeded or instructions given on how it is to be limited.

- Compression around bony prominences should be treated with caution, as oxygen tension changes due to compression pressure are more significant in these locations.

- The use of "bung" type retainers is not advised as their disadvantages are significant in comparison to clip type retainers.

- It is suggested that "bung" type dressing retainers, if used, should be applied "face down" in order to minimise pressure but also allow inspection for cleanliness.

- Further work is required to understand the compression characteristics and advantages of all clip designs.

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