The Maggot Manual

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1. What to do if you find maggots on a patient

Feral maggots (maggots that are not born in a sterile clinical environment) can be hazardous to a wound, they carry disease and bacteria that can cause other complications for a patient who is already compromised with a wound. There are over 11 000 species of flies that can cause harm to humans, flies can carry parasites and breed parasites in their own body or mechanically transport viruses and infectious bacteria as they travel from site to site e.g. faecal deposits, garbage bins, waste sites etc[i].

Female flies have a keen sense of smell, and will travel to lay eggs in this suitable environment. As a result they can find rotting organic material such as infected wound tissue or decaying meat from a long distance[ii]. Once the suitable environment is found and eggs are laid maggots may be found in a wound bed, ears or other cavities.

When feral maggots are discovered in wounds or cavities it is important remove them whether this is at Emergency Department, Ward level, Outpatient or Community setting.

It is important to be aware that patients who have allergies to Soybeans, Eggs or fly larvae have the potential to develop an allergy to maggots[iii].

At present Maggot Debridement Therapy (MDT) is not utilised in the Northern Territory as there are no facilities to breed sterile maggots for wound care. In Australia Sydney's Westmead Hospital is the only place where therapeutic maggots are bred in laboratory conditions[iv]. Unless the patient advises or you have written confirmation that the maggots are sterile they must be removed to prevent complications arising from feral maggots.

Only Maggots from the Green Bottle fly in the genera of *Phaenicia or Lucillia,* are used for wound management as these maggots consume dead tissue while leaving live tissue intact[vvi]. Not all maggots differentiate between dead and live tissue, leaving unidentified maggots in a wound could lead to further tissue damage.

Maggots that feed on live and dead tissue become highly invasive, an example is the larvae of the Screw Worm fly. It is particularly dangerous laying eggs in wound margins or mucous membranes such as the nose or vagina, the maggot is highly aggressive flesh eating larvae that burrows down into tissue causing large amounts of damage or even death[vii] [viii]. This fly is not established in Australia, but is prominent in Papua New Guinea, it is in the coastal swamp lands near Torres Strait and is endemic in Australia's northern neighbours in the indo pacific region, there is potential for this maggot to be present in patients who present to a health region in the NT top end[ix] [x].

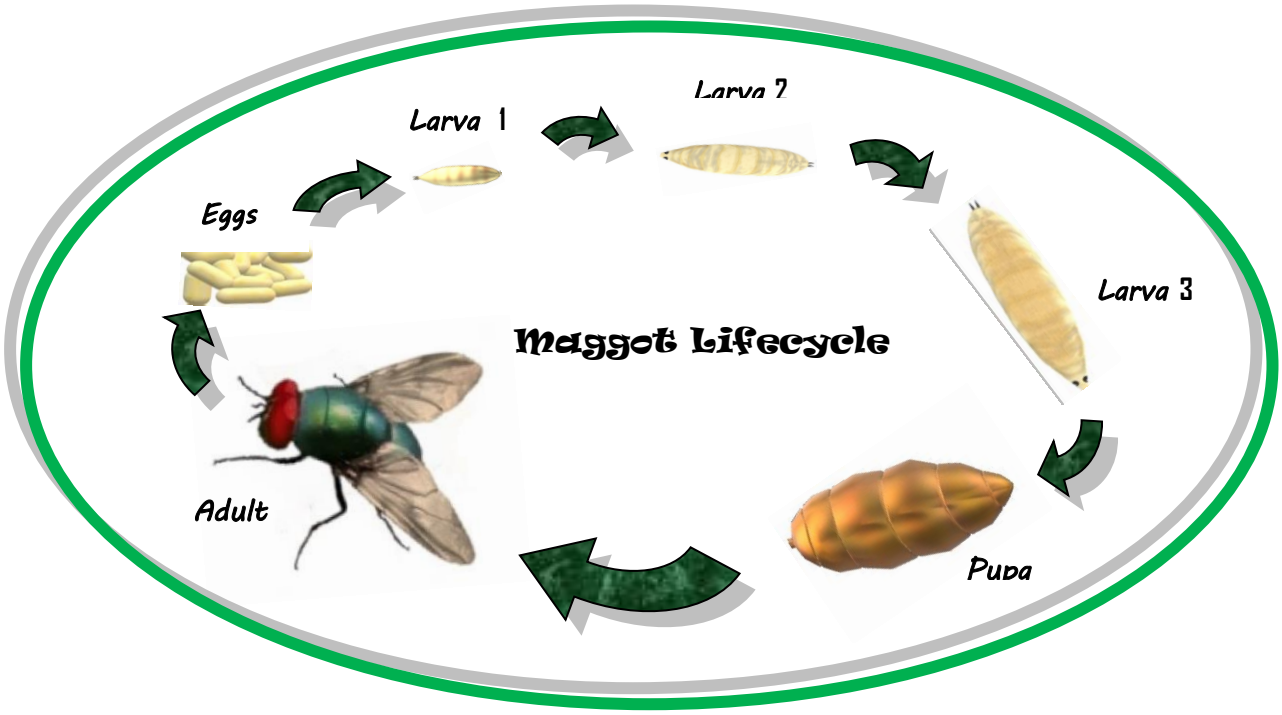
Surveillance is conducted by the animal health program Australia to prevent entry of the screw worm fly to the country. Areas under surveillance include Broome, Kalumburu in WA, Darwin and surrounding areas, East Arnhem Land in NT and Weipa, Torres Strait Islands, North Peninsula area and Coen in QLD. If an invasive maggot is found in a wound it must be contained, collected to be sent for testing and reported to biosecurity immediately[xi].

Key points if maggots are found in a wound

- Identify location of maggot infestation
- Identify the type of wound infested
- Identify if they are medicinal (i.e. from interstate patient)
- All feral maggots in wounds must be removed or destroyed
- Feral maggots in the wound introduce pathogens and may cause harm to live tissue.
- The type of maggot cannot be identified until it turns into a fly
- Assess if live wound tissue is damaged, if so contain maggots immediately and contact biosecurity services. Emergency Animal Disease Watch Hotline 1800 675 888[xii]

Note: Eggs hatch within 8-10 hours of being laid, they remain larvae for up to 6 days in warm climates and will reach full size in approximately 40 hours of hatching[xiii].

They increase rapidly in size, moult twice until fully grown at day 5 to 6, where they then leave their food source and find a place to turn into pupa[xivxv].



2. What are the best methods for maggot removal?

The most important thing about maggot removal is to identify the location of the wound or area infested, ascertain any problems that could arise using the various techniques for maggot removal, then implement the safest technique to provide the best outcome for the patient. No matter what technique is used the area should be checked again in 24hrs to ensure all maggots have been removed, as small maggots are difficult to see, it is possible on review you may find maggots still residing within the wound area.

Mechanical removal:

Use damp gauze to wipe maggots out of the wound, once this has been performed the below methods can be used to remove residual maggots.

Irrigation with saline or water:

Irrigation can lift off medium sized maggots off the surface of a shallow wound. Small maggots are difficult to irrigate off tissue as they tend to stick in the wound crevices'.

Irrigation with betadine or chlorhexidine:

These specific antiseptics will kill maggots and assist in killing pathogens that have been introduced by feral maggots. It is important to use saline to irrigate out the antiseptics prior to dressing the wound, to reduce the chemical impact on wound tissue.

Irrigation with suction:

By irrigating the area and using a soft Y suction catheter you can lift most maggots from the wound base. This is also effective if you have maggots that have collected around a tube or drain site (be aware of where the drain or tube site goes, irrigation may be contraindicated and if so only suction may be employed in this region).

Suction without irrigation:

This can be utilised if there is a risk of irrigating an area (e.g. lung cavity), maggots can be collected by a suction catheter, however dry suction can be more time consuming, avoid use on friable tissue as it may cause bleeding.

Capture:

Catching maggots by forceps can be used before or after irrigation to catch any maggots that prove difficult to remove. Use only non-toothed forceps to prevent damage to tissue that maggots are residing in, if a maggot is in a cavity you may have to implement the hide and find technique.

Hide and Find:

Hide and find relates to the fact that maggots are photophobic and when exposed to light they will migrate to the darkest part of the wound base, if they retreat into a cavity it makes them very difficult to catch. By covering the wound with a gauze or padding to make the area dark for a short time 10-20 seconds, you will find they will migrate to the top of the wound where you can catch as many as possible with forceps or suction catheter before they retreat back into the cavity again, repeat this action until all are gone. This type of 'peek-a-boo' maggot collection is time consuming but is a good method to encourage maggots that are deeply embedded in cavities to move to the surface. If they persist at the base of the wound and cannot be removed suffocation may be the next option.

Suffocation:

Smaller maggots are very hard to see and they move fast making them very difficult to catch, as a result you may need to remove what you can then suffocate the rest. There are some areas where irrigation, suction or capture techniques cannot be employed e.g. vaginal region, burr holes, ears, fungating tumours, or where there is a risk of rupturing vessels by using these techniques. Suffocation can be used on other areas after initial irrigation to kill any remaining maggots. To survive maggots require oxygen room to move, by creating a wound environment that has limited oxygen, suffocation and death of maggots can be achieved. Use a thick layer of paraffin ointment over the wound base, or a triple layer of paraffin gauze or filling a cavity with hydrogel. The maggots will drown or suffocate as they find it difficult swim out of the gel or to breathe in parrafin. After twenty four hours they will come off in the dressing or be broken down by macrophages.

3. What removal methods are contraindicated?

Hydrogen Peroxide is contraindicated in the removal of maggots.

It is thought that hydrogen peroxide kills maggots this is not true.

Peroxide originally was used to lift hiding maggots out of cavities by using the bubbling effect of the solution. However the contraindications of using peroxide in a wound outweigh the benefit of a 'quick fix' of lifting the maggots out of the wound[xvi] [xvii]. The use of peroxide for irrigation in a wound has the potential to lead to disaster.[xviii].

Peroxide is contraindicated because:

- Is cytotoxic to the wound tissue especially fibroblasts[xix]
- Can cause subcutaneous emphysema
- Can cause air emboli if irrigated into deep cavities[xx]
- Increase inflammatory response of wounds, causing delayed healing[xxi]
- Can ulcerate newly formed tissue
- Risk of fatal oxygen emboli [xxii][xxiii] [xxiv]

Peroxide is non selectively cytotoxic, that is it does not differentiate between bacteria, white blood cells and vital wound healing cells such as fibroblasts. This is because the primary mechanism of action is to destroy cell walls regardless of the type of the cell [xxvxxvi].

Haller, Faltin-Traud, Faltin and Kern (2002)[xxvii] state that:

"We emphasize that hydrogen peroxide is a dangerous and unsuitable agent for routine wound irrigation and debridement"

This statement was made after following a case study of a patient who was 33yr old healthy woman that suffered an air emboli in surgery after irrigation of a vulval abscess wound with 3% hydrogen peroxide.

Since 1mil of peroxide can produce 10ml of oxygen; the emboli that can be produced in a cavity can be significant[xxviii] [xxix], is not a safe option for wound irrigation.

Following on from 2002 multiple reports of air emboli due to use of hydrogen peroxide have been reported including significant events as stated by Peng, Cao et al (2020):

> "**fatal ischemic brainstem lesions and pneumocephalus during spinal surgery, tension pneumocephalus and oxygen emboli during a high grade glioma surgery, portal venous gas after accidental ingestion of concentrated hydrogen peroxide, cardiac arrest during arthroplasty, and air embolism after irrigation of external fixator pin sites with hydrogen peroxide[xxx]".**

Hydrogen peroxide should be avoided as routine wound management option and not used for irrigation in removal of maggots from wound sites[xxxi].

4. Maggot General Information

4.1 The Green Bottle Fly

The green bottle fly, Phaenicia (Lucillia) seicata[xxxii] are a common fly in Australia, they breed by laying eggs in grouped clusters on organic material. Maggots breathe through spiracles on their bottom which are visible when the maggot forms the hardened shell of the pupa prior to hatching into the mature adult fly.

The larvae undergo a lifecycle of approximately 5-6 days before forming into a pupa then hatching into a newly formed adult fly[xxxiii]. The Green Bottle fly larvae are the preferred choice for wound debridement because of the enzymes produced by the maggot larvae. These enzymes only breakdown devitalised tissue as a result healthy tissue remains unaffected[xxxiv].

4·2 How Maggots Achieve Debridement

Maggots achieve debridement through enzymatic breakdown of devitalised tissue, these enzymes include collagenase and other powerful enzymes to breakdown devitalised organic matter· Maggots are capable of breaking down 25mg of non-viable tissue in a wound in 24 hours[xxxv]·

When feeding maggots focus in a head down position to access devitalised tissue, they use breathing spiracles located on their bottom to allow unrestricted breathing whilst feeding· Once the tissue is softened into a semi liquid form it is reabsorbed and digested[xxxvi] [xxxvii].

Research indicates by using maggots for wound debridement it reduces the need for antibiotics, this is a positive factor, as with less need for antibiotics it aids in a solution to the growing problem of antibiotic resistance· Maggot secretions have anti-microbial properties that prevents the growth of bacteria in the wound, it is seen as a natural way to sterilize a wound[xxxviii], these secretions include allantoin, urea, phenylacetic acid, phenylacetaldehyde, calcium carbonate[xxxix]· These secretions make maggots highly efficient at removing multi-drug resistant bacteria from a wound[xl]·

Chronic wounds are known to have a mix of devitalised necrotic and fibrous tissue, whilst at a microscopic level there is a biofilm (a matrix of polysaccharide polymer housing numerous and complex array of microbes)· The structure of a biofilm behaves like a miniature city providing nutrients and waste disposal by channels formed between the matrix under the umbrella covering[xli]· This sophisticated structure makes biofilms impenetrable by antibiotics, whilst they can harbour harmful pathogens within its matrix, the bacteria that grow within a biofilm are 1000 times more resistant to antibiotics than the same bacteria not in a biofilm[xlii]·

Bacteria such as Staphylococcus epidermidis are responsible for biofilm formation in chronic wounds, which can lead to tissue infection that cannot be diagnosed by wound swabs, as the causative pathogen of the infection is not identified as it is protected by the biofilm·
Studies have demonstrated that maggots disrupt and breakdown of biofilms[xliii] in wounds, and now it has been discovered their secreations prevent new biofilm from forming[xliv]·

MDT could be seen as a symbiotic relationship, Leong 2009[xlv] sums it up nicely stating:

> **"using maggots for wound care and debridement is a win-win situation for patients and maggots· The patient gets his or her wound cleaned quickly and efficiently and the maggot gets a good meal"·**

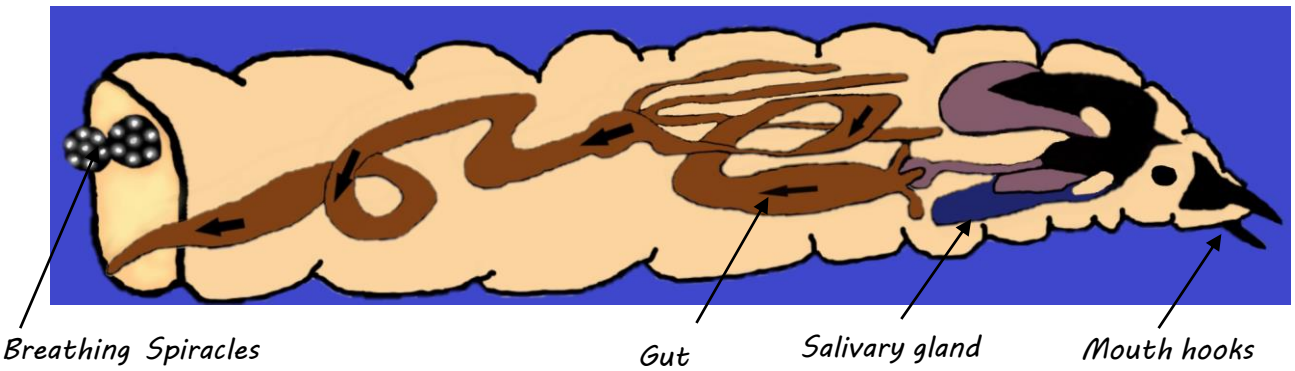
Ultimately maggots come out on top as the champions in wound management as they effectively debride / clean the wound, disrupt biofilm, and reduce the need / frequency of antibiotic therapy[xlvi] which results in improved wound healing and better patient outcomes·

4.3 Maggot Anatomy

A maggot has hooks called 'mandibles' located at the mouth, these allow the maggot to attach to its food source and assist in movement around the tissue surface. They do not have the ability to bite as they do not have teeth, they secrete enzymes to liquefy the tissue[xlvii], the body of the maggot has small spines which scrape along the surface of the wound, loosening non-viable tissue to be liquefied.

The mouth hooks pull the maggots body along the wound surface and help probe all gaps and spaces within the wound which loosens off tissue in these spaces, similar effect to using a scrubbing brush in a wound[xlviii]. This scraping effect on the surface of their food source, disrupts the tissue membranes making it easier to break down the tissue as it travels, although this has not been confirmed as the true reason for this action[xlix l].

The Maggot Digestive System



4.4 Therapeutic Maggots

In the first half of the 20th century when world wars were at their peak of devastation and destruction, major injuries were a common sight with potentially life threatening injuries that lead to fatal infections, amputations and festering wounds. It was in this time that it was noted that those soldiers who had maggot infested wounds were more likely to survive, they did not develop systemic infections or die from infected wound with rotting tissue[li].

It was recognised that maggots were becoming the saviour of limbs and lives, as a result maggot therapy became a path for ongoing wound management therapy. Even so it took until the late 20th century before medicinal maggots were developed specifically for wound management purposes[lii]. The FDA of America did not approve of maggot therapy until 2004, it is now a recognised therapeutic treatment for wound debridement[liii liv].

As maggot therapy becomes more popular and acceptable as a form of debridement of wounds, research has continues to understand the behaviours and benefits of MDT, including that maggot secretions inhibit the pro-inflammatory response of monocytes in the human cellular system[lv lvi lvii]. MDT has multiple benefits to wound healing with three main mechanisms of action, debridement, disinfection and improving the speed of wound healing[lviii].

Research has shown that healing time using MDT is significantly lower than standard wound therapy options[lix], even with the known benefits the use of this modality remains low[lx], one authors indicates worldwide that "less than 5 percent of patients who are destined for amputation are given a trial of MDT, even though published studies show that 50 to 70 percent of amputations could possibly be prevented[lxi]." This could be due availability of the therapy or the acceptance maggot of therapy as an option by both patient and staff.

Chronic wounds are known to stagnate and fail to progress along the normal wound healing cascade due to a pro-inflammatory status of the wound, where the wound becomes 'stuck' in the inflammatory stage healing. MDT suppresses the pro-inflammatory nature of chronic wounds, which tips the wound back into the normal wound healing cascade[lxii].

Researchers have been analysing the enzymes, secretions and excretions produced by maggots to produce a therapy that can be applied to the wound without the need of the physical maggot. One researcher has developed a prototype hydrogel containing insect derived active products[lxiii]. Whilst another researcher has combined E.coli and the maggot chymotrypsin-like protease, to develop the pure form of enzyme without the physical maggot component[lxiv]. As yet nothing has mass produced to replace the humble maggot, however in the future we may see MDT without the maggot, which may make this therapy more widely available and acceptable to staff and patients alike[lxv].

4.5 Sterile Maggots?

This does not mean they do not have the ability to breed, the sterilisation process removes any pathogens on the surface of the larvae eggs prior to hatching so when the maggots emerge they will not be carry any pathogens that could be introduced into the wound[lxvi]. After sterilisation the eggs are placed on a medium in sterile container, once hatched this medium keeps the larvae alive but will not provide enough nutrients for them to grow rapidly, otherwise they are of little use when applied to a wound[lxvii].

4.6 Clinical use of Maggots

Protection of surrounding skin is essential when using maggot therapy, the standard form of protection is a hydrocolloid sheet cut placed on the peri-wound skin usually a 3 to 5cm margin. Once maggots are introduced in to the wound a fine mesh is applied on top so the maggots can breathe but not escape, the mesh is cut approx 1-2cm larger than the wound so it can be taped to the hydrocolloid boarder with Fixomul™ or similar tape[lxviii] to prevent escapees. An absorbent pad is applied over the mesh to absorb any exudate and changed when soaked. The padding must not be strapped tightly and must not be occlusive as the maggots require room to move, and require oxygen to survive, the pad should only be taped down with cloth tapes not film dressings[lxix]. The process of containing maggots has become easier with the option of biobags[lxx] which contain the maggots in a defined space, allowing ease of application and removal without the risk of escapees.

The recommended amount of maggots required for a wound varies, dosage is generally 5 to 7 maggots per square centimetre of wound surface area[lxxi]. The general rule is no more than 10 maggots per square centimetre of tissue and less if there is only limited necrotic tissue at the wound base.

A therapeutic cycle of maggot therapy is three days, they then become full, cease producing enzymes to breakdown tissue and fall of the wound as they no longer require nutritional intake[lxxii]. If a biobag is not used any remaining maggots can be removed by methods discussed earlier in this manual.

One maggot can remove approximately 25mg of nonviable tissue in a 24hr period[lxxiii]. A single application of MDT is usually sufficient to provide adequate debridement of a wound, more can be reapplied if there is particularly stubborn necrotic tissue that requires further maggot therapy[lxxiv].

5. Summary:

The main purpose of this manual is the identification of feral maggot in a wound and knowing the appropriate measures to safely remove them and in rare cases in the NT knowing how to care for them if they are therapeutic.

Understanding the differences between feral and therapeutic maggots is essential to ensure that the patients' safety is not compromised through introduction of potential hazardous pathogens due to feral maggots living in a compromised wound, or leaving maggots insitu that may be invasive or detrimental to live tissue.

This manual provides advice for safe practices for removal of maggots from the wound bed, focusing on evidence based practice to ensure optimal outcomes are achieved for the patient with maggots in the wound.

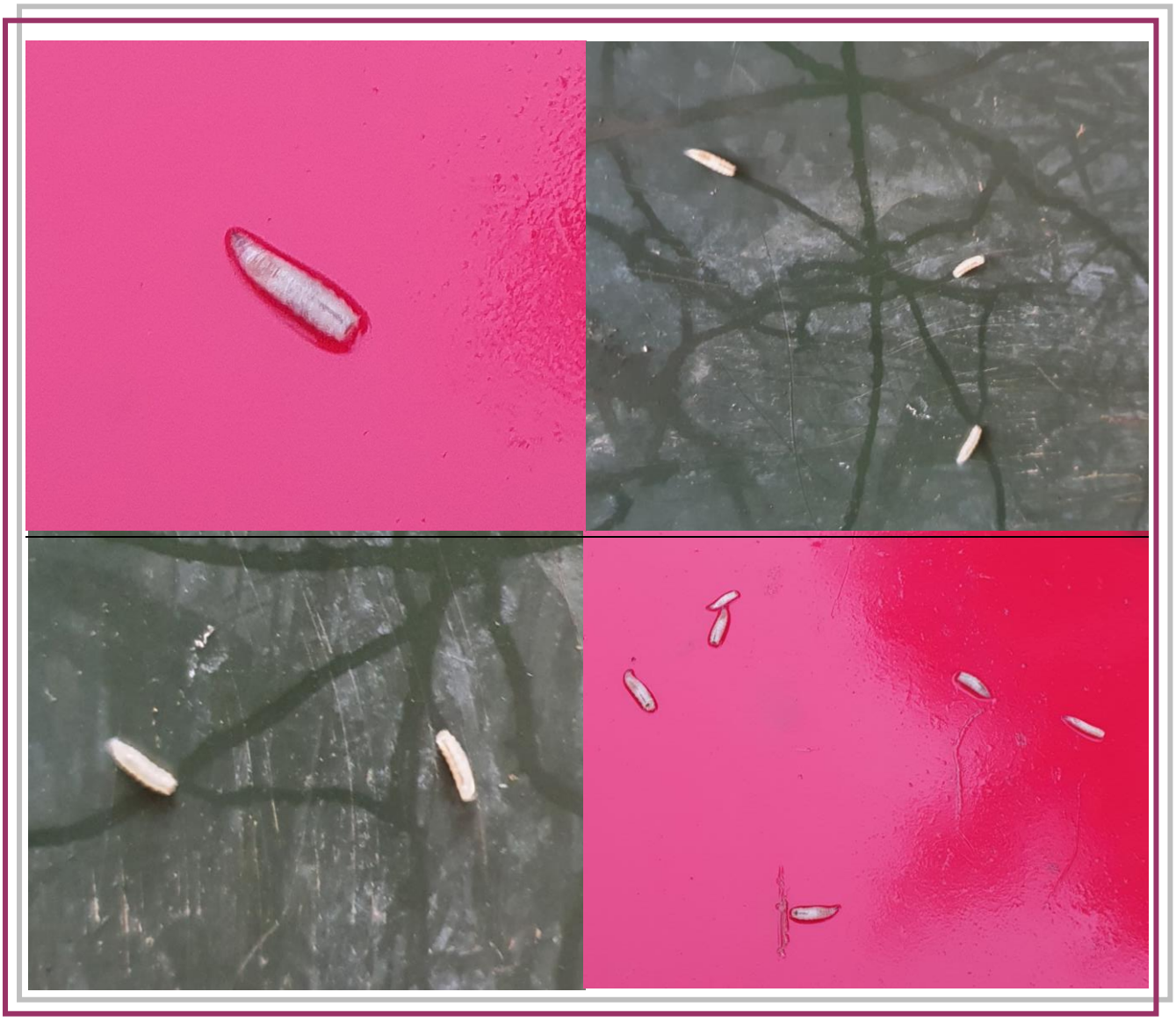
MDT is an effective method of debridement and stimulation of chronic wounds, this therapy has the ability to reduce inflammation, breakdown biofilms and prevent formation of new biofilms in chronic wounds.

The increasing evidence of antimicrobial efficiency of maggot debridement indicates that this therapy is underutilised and possibly should be considered more of a first line treatment for chronic difficult to heal wounds instead of a last resort method when all else has failed.

With an increase in antibiotic resistance and overuse of antibiotics in chronic wounds with reoccurring infections, the benefits of maggot therapy are high and should be considered as a regular intervention technique, however with limited availability in Australia this restricts the capacity to achieve this in real life practice.

The barriers to maggot therapy include acceptability of maggot application (patient and staff), and the availability of maggots in the Australian Health Care setting. Since there is increasing evidence that maggot therapy is a safe and cost effective wound care option with many benefits as discussed in this manual...

...The question remains should consideration be made to develop a local sterile maggot therapy service in the future to make therapeutic maggot debridement therapy (MDT) more accessible in the Northern Territory?.



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