Review Article

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Maggot debridement therapy and innovation from myiasis - A review

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Abstract

Maggot debridement therapy is the introduction of live and disinfected fly larvae in a wound in order to aid cleaning and healing. This technique was discovered as a beneficial effect of colonization of human tissue by fly larvae (myiasis). This discovery was made during the World War I when it was observed that injured soldiers whose wounds were infested with maggots healed faster than their counterparts whose wounds were free from maggots. In this therapy, the larvae of Blow fly (*Lucilia sericata*) are used because they feed exclusively on dead tissues. There are two different ways through which these maggots are applied into the wound, namely, free range dressing and biobag dressing. The mechanism of action of the maggots during debridement involves secretion of digestive enzymes which breakdown the dead tissues, liquidizing it before ingesting the liquefied contents of the wound. They also secrete antimicrobials which inhibit microbial growth in the wound, thereby disinfecting it. This therapy has been successfully used in the treatment of leg ulcers, deep and diabetic wounds in humans. The advantages of maggot debridement therapy are enormous. The cost of using it is relatively low, it quickens healing of wounds, and it is painless. However, the patient may experience irritation and itching at the wound site which is associated with larval movement in the wound. The adoption of this therapeutic wound management is advocated as practical evidence show that it has proven effective in the management of diabetic wounds more than conventional medical practices.

Keywords: Maggot therapy, Debridement, Myiasis, Wound management, Blow fly (*Lucilia sericata*).

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INTRODUCTION

Wound treatment remains one of the major areas in health sciences which has attracted attention of health professionals as a result of increasing occurrence of chronic wounds and the associated socio-economic significance to individuals and government (Brown, 2013). Fly larvae (maggots) have been identified to play significant roles in debridement and healing of wounds. Maggot debridement therapy was first

discovered and introduced in the USA in 1931 (Baer, 1931). The therapy was applied in different hospitals until 1940 when its use became reduced because of the advent of antimicrobials (Whitaker *et al*., 2007). However, the therapy was reintroduced in 1990s and has spread through many other countries in recent years including Nigeria.

Maggot wound therapy is the application of live larvae to wounds in order to help in wound debridement (cleaning), disinfection and healing. A maggot infestation on a living vertebrate is called myiasis and when the colonization is limited to a wound, it is termed wound myiasis (Choudhary *et al*., 2016). The idea of maggot debridement therapy emanates from the discovery that wounds that are naturally infested with maggots are usually free from infection and debris, hence heal faster (Sherma, 2003). Maggot wound therapy thus, is a therapeutic wound myiasis which is controlled in ways that optimize efficacy and safety. The application of this therapy has revealed that the most significant and obvious change in maggot treated wounds is debridement which is the removal of dead and infected tissues to aid in wound healing (Steed, 2004). It is also aimed at removing foreign materials from the wound. The therapy is mostly important for deep wounds that continue to decay despite conventional wound healing treatments. It is also usually applied to wounds that are trapped in the first stage of healing, hence, when decayed tissues are removed by the maggots, the wound can resume the healing process (Adele *et al*., 2005)**.**

The species of fly whose larvae are usually applied for the wound debridement is *Lucilia sericata*; the choice of this species among the flies implicated in myiasis is because its larvae infest, colonize and feed exclusively on dead and decaying tissues. This follows that the tendency of the maggots invading healthy tissues has been ruled out (Whitaker *et al*., 2007). The method of maggot therapy involves a myiasis-controlled process of carefully selecting the species of fly, disinfecting the larvae, maintaining it in the wound and integrating quality control measures throughout the process (Francesconi and Lupi, 2012).

The advantages of wound debridement by larvae cannot be overemphasized as they prevent contamination of healthy tissues by diseased and decayed ones, reduce complications of infection, minimize scaring and help healthy tissues to grow (Pritchard and Nigam, 2013).

Review Methodology

A detailed search of the major search engines was conducted. This included Google scholar and Pubmed. Literature reviews from related articles were used for this work. Research findings/results of closely related research works were included as evidence of practical application of this therapy. Relevant information was also gotten from related textbooks. Various combinations of the following search items were made; maggot, maggot therapy, wound, wound management, maggot debridement, maggot wound therapy, biodebridement, biosurgery, larval debridement therapy, myiasis (Jordan *et al*., 2018; Lin *et al*., 2015; Nwaeburu and Alishlash, 2016).

Myiasis

Myiasis is the colonization or infestation of human or animal tissues with fly larvae (maggots) which feed on the host's dead or living tissues, mucus or host's ingested food (Ubachukwu, 2019). It is mainly an infestation of veterinary importance though humans are also affected especially workers in livestock farms. Studies have shown that the most common locations on the human body for cases of myiasis are wound, subcutaneous lesions and boils. Colonization of the body with fly larvae may however occur anywhere on the body such as the ear, the nostrils, the mouth, the vagina and the anus (John and Petri, 2006).

Myiasis-causing larvae have varying abilities of invading their hosts. Some can attack and invade healthy and unbroken skin while others have capacity of invasion only when the skin is broken especially through injury (Millikan, 1999). The adults of myiasis-causing flies are free-living and are usually attracted by different kinds of animal odours such as those from fresh blood, wound, natural cavities of the body such as nostrils, mouth, ear, vagina and rectum especially when such cavities are diseased. Most of the myiasis-causing flies belong to the order 'Diptera'. Examples are Housefly (*Musca domestica*), Bot flies (*Dermatobia hominis*), Screw worms, Blow flies (*Lucilia sericata*) (Sunder and Vikram, 2010).

Classification of Myiasis

Myiasis has been classified into two categories, namely; parasitological and medical classification.

Parasitological Classification of Myiasis

From the parasitological point of view, myiasis is grouped into 3 based on the larvae's level of dependence on the host. These include

Obligate Myiasis

The fly larvae in this group infest and feed on healthy host tissues. They only live as parasites and cannot thrive without being parasitic on a living host, eg. larvae of Screw worms and Bot flies.

Facultative Myiasis

This is a kind of myiasis in which the larvae colonize and feed on wounds, diseased and dead tissues. Some of the larvae in this category can also be parasitic if opportunity for such existence becomes available whereas others normally breed exclusively on dead and decaying organic matter, eg. *Lucilia sericata*.

Opportunistic, Accidental or Pseudomyiasis

This is a group in which free-living and saprophagous larvae of fly species colonize the human body. It is usually as a result of accidental ingestion of eggs or larvae of insects eg. *Musca domestica*, *Muscina spp*., *Eristalis tenax* (rat-tailed maggot) (Zumpt, 1965).

Medical Classification of Myiasis

Myiasis has been classified medically based on the part of the body that is affected. These are;

Cutaneous myiasis: This is myiasis of the skin and tissues associated with the skin.

Visceral myiasis: This is myiasis of internal organs.

Gastro-intestinal myiasis: This affects the alimentary canal.

Ocular/ophthalmic myiasis: This is myiasis of the eyes and associated tissues.

Auricular myiasis: This is myiasis of the ear.

Nasopharyngeal myiasis: This is myiasis of the nose and pharynx.

Cerebral myiasis: This occurs when the brain is involved.

Traumatic myiasis: This is as a result of invasion of wounds by the larvae. Most of the larvae that cause traumatic myiasis are facultative (Zumpt, 1965).

Biology of Maggot

Maggot is the larval stage in the development of insects. It is the stage of metamorphosis of flies that accumulates products and normally give rise to a pupa which finally develop into the adult stage (Hardouin, 2003). It follows that maggot is a derivative of fly egg after varying degrees of incubation in organic materials which depends on environmental conditions. Maggot thrive most in wetland environment where the danger of drying is minimized and can be found in soil, plant and animal tissues as well as other organic materials (Bismillah *et al*., 2015).

The lifecycle of maggot-producing flies follows same pattern of complete metamorphosis which include four developmental stages, name; egg, larva/maggot, pupa and adult. The duration of this development varies from species to species but generally depends on temperature, humidity and food availability (Bouafou *et al*., 2006). Fly-producing maggots naturally lay their eggs in wet and decaying organic materials such as dead and decomposing plants and animal materials (Bismillah *et al*., 2015).

Maggots lack legs and a separate cephalic capsule while the mouthparts are reduced with the presence of oral hooks for feeding. Their sizes range from 0.4 - 1.5cm long depending on age in days before transforming to pupa (Hardouin, 2003).

Importance of Maggot

Maggots serve as food to poultry birds and fish because they are rich in protein.

They also help in decomposition of decaying organic materials, hence increases the fertility of

the soil for farming. Maggots have also been used as bait in fishing.

In forensic entomology, analysis of maggots found in decomposing bodies can reveal information about the time of death and presence of specific drugs as well as providing clues about crime location.

Maggots act as parasites of man and animals as they infest their bodies (myiasis).

Medically, they are used for the treatment of wounds through debridement. This hastens healing as the maggots remove the necrotic parts of the wound and avoid contamination of healthy ones.

Maggot Debridement Therapy

Maggot therapy is a kind of wound management in which disinfected larvae of a particular insect species are applied to wounds to feed on dead tissues, remove pus and metabolic wastes, thus promote healing (Valachova *et al*., 2014). It is also called biodebridement, larvae therapy (Turkmen *et al*., 2010), biosurgery, biotherapy and biosurgical debridement (Cickova *et al*., 2013). Though many species of fly larvae have been implicated in myiasis, only a relatively few are known to have medical application (Francesconi and Lupi, 2012). Currently, maggots of Blow fly (*Lucilia sericata*) are the most widely used species for this therapy because of their preference for feeding on necrotic tissues over healthy ones (Sherma *et al*., 2007; Nigam *et al*., 2006a). During debridement therapy, live and disinfected maggots are introduced to wound for debridement, disinfection and enhanced wound healing (Gottrup and Jorgensen, 2011).

Maggot debridement therapy is an effective means of wound management which is mainly appropriate in large wounds where painless removal of dead tissues is needed. This is achieved through the release of proteolytic enzymes which contain secretions for dissolution of necrotic tissues from the wound (Blake *et al*., 2007). The species of maggots used for debridement feeds only on dead tissues and not on healthy ones (Chambers *et al*., 2003). According to studies, some other mechanisms of action of this therapy that are believed to contribute to its eventual outcome include:

1. Inhibition of bacterial growth by producing and releasing ammonia into the wound. The presence of ammonia increases the PH of the wound (Smith *et al*., 2006).
2. They enhance wound healing by stimulating production of granulation tissues after eating all the dead and infected ones. The secretions contain growth stimulating factors for fibroblast, allantoin, Calcium cystein and glutathione (Gupta, 2008).
3. Breakdown of existing biofilm at the wound bed and inhibition of growth of new biofilm.

Methods of Application of Maggots to Wounds

Maggot therapy is an organized technique in which effective and safe species of fly larvae are selected and disinfected for wound management. These larvae are known as medicinal maggots. They are applied on the wound using special dressings which prevent them from crawling out of the wound (Sherma, 2009). Studies have revealed that maggots of *Lucilia sericata* are used in this technique because of their non-invasive nature. The wound is cleaned with salt solution in order to remove dirt and make it grease-free before the application of the maggots (Whitaker *et al*., 2007). Two different methods of application of the maggots to the wound include:

1. **Free range dressing (Direct contact):** In this method, maggots are applied directly to the wound bed and covered with gauze bandage. They remain in contact with the wound for 3 days and freely roam over the surface of the wound as they search for and remove dead tissues (Brown, 2013). After 3 days, the maggots are removed and the wound is cleaned with physiological saline or salt solution followed by introduction of another set of maggots (Gottrup and Jorgensen, 2011).
2. **Biobag dressing method:** In this method, maggots are enclosed in a special bag that contains polyvinyl alcohol space. The bag is made of large mesh sizes which permit the movement of maggots to the wound. Usually, 5-10 maggots are introduced per centimeter square of wound surface for 3 days

(Grassberger and Feischmann, 2002). The bags with the maggots are replaced afterwards followed by cleaning of the wound using physiological saline. The wound surface is also kept wet on daily basis with the physiological saline (Blake *et al*., 2007). The gauze bandage which is used to cover the wound is changed daily to avoid odour emissions and accumulation of wound fluids that could be lethal to maggots (Gottrup and Jorgensen, 2011).

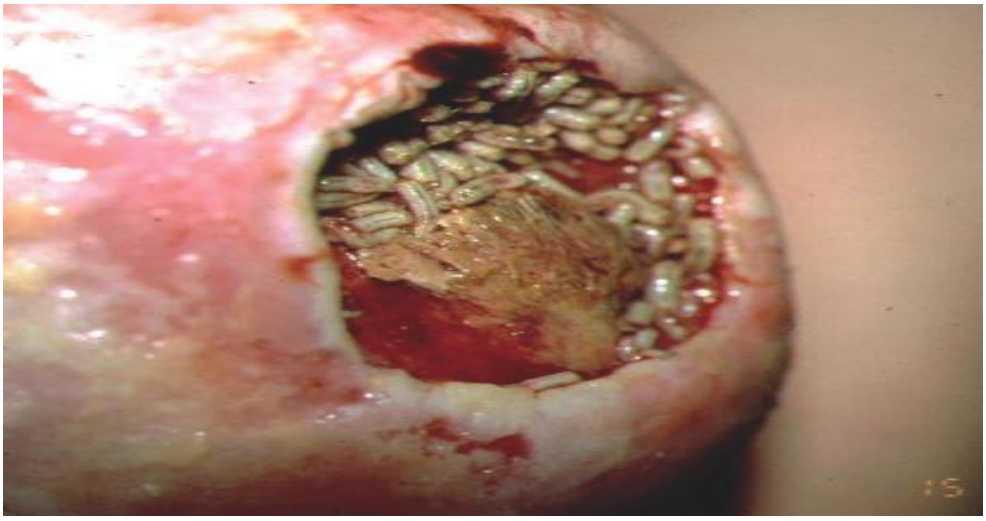

Figure 1: Maggots on the surface of wound. Source: Dariusz *et al*., (2022)

Production and Disinfection of Larvae for Debridement Therapy

The maggots used for debridement therapy are aseptically produced in the laboratory. This is achieved through collection and raising of eggs from the gravid female *L. sericata*. The eggs are first disinfected with Sodium hypochlorite after collection (Sherma *et al*., 2007). It is advised that the maggots are not left without use for long after being microbiologically certified fit for use. This is to avoid further maturation, though this can be controlled by storing at a temperature of 4-8^{0}C for 2-5 days (Morrison, 2010; Blake *et al*., 2007). The maggots are applied in the wound in batches. The batches are applied to feed on dead tissues in succession. The larvae are average of 1-2mm in size at the time of application in wound for debridement, they later grow to an average size of about 1cm within 3 days of feeding and are replaced with another batch (Gottrup, 2005).

Maggot Debridement Therapy in Humans

Maggot debridement therapy has successfully been used in the treatment of wounds especially in diabetic patients. This is because the maggots can debride wound beds and stimulate wound healing as well as provide antimicrobial activities in diabetic wounds. In one account, maggot debridement therapy resulted in improvement and healing of wounds of 17 out of 23 diabetic patients treated (Michelle *et al*., 2011). In a related report, Harikrishna *et al.,* (2021) revealed that 30 patients with diabetic lower limb ulcers were treated with maggot debridement therapy. This according to the report included 9 females and 21 males. They showed that the maximum debridement of wounds was achieved in 96.6% of the patients and no adverse reactions were observed. Sherma (2003) also reported that maggot therapy was more effective in treating non healing foot and leg ulcers in male diabetic patients compared with the conventional medical care. This was the outcome of a comparative study of 18 diabetic patients who were treated with either maggot debridement therapy or conventional medical and surgical therapy.

Maggot debridement therapy has also served as a good alternative to the management of chronic non-healing wounds (Cambal *et al*., 2006). This therapy has reportedly proven effective in the treatment of non-treatable leg ulcers in patients in whom conventional therapy failed. The report showed that the therapy enabled all leg ulcers to

either heal or reduce in size after 4-8 weeks of follow up management (Naik and Harding, 2017).

Aminu Kano Teaching Hospital, Kano State has championed maggot debridement therapy in Nigeria and it is the only maggot therapy center in the country at the moment. The centre collaborates with Orthopaedic unit of the hospital and serves as a final referral centre for patients prior to amputation if treatment fails to achieve the desired effect. According to a report, the centre had successfully treated and discharged 30 patients who were suffering from chronic wounds as at December 2020 (Salisu, 2021). There is thus hope that more Nigerians suffering from diabetic and ulcerous wounds can get quick healings as well as saved from amputation of their affected limbs.

Figure 2: Effect of maggot Debridement Therapy on wound.
Source: https://www.shutterstock.com/search/maggot+therapy

Advances in Maggot Wound Therapy

Advances in the area of maggot wound therapy started in 2004 when the U.S Food and Drug Administration approved maggot debridement therapy as a "prescription only" treatment. This prescription certifies maggots as single-use medical device (Jordan *et al*., 2018). Studies have however revealed that many patients with non-healing wounds also suffer from other diseases such as neurological, hormonal, rheumatic and cardiovascular diseases (Romeyke, 2021). They may also suffer depression and immobility (Pereira *et al*., 2001).

The recent advance in maggot therapy is the integration of the therapy into a holistic, multimodal therapeutic approach. Holistic therapy is the therapeutic approach that treats the whole person rather than concentrating on the treatment of individual signs and symptoms. In this approach, a therapy plan with goal is made based on the individual patient's comorbidities (Romeyke, 2021). In keeping with this holistic approach, Choobianzali *et al.,* (2022) reported a case of a 51-year old male patient with a history of 5-years type 2 diabetes and has had diabetic foot ulcers. Treatment of the diabetes and maggot therapy for diabetic foot ulcer was adopted for holistic treatment. According to the report, the ulcers healed three months after maggot debridement therapy. Gunasegaran *et al*., (2022) also reported that supplementary treatment offered in addition to maggot debridement seemed to promote wound healing and reduce non-viable tissue rate in most patients. They also revealed that the method of maggot debridement therapy applied should depend on the characteristics and the location of the wound, for instance, free larvae range is easier to apply to irregular and deep wounds than biobag method.

Maggot therapy is thus currently incorporated as an innovative therapy option for wounds that are

difficult to heal while the comorbidities are treated concurrently for better result. It is now applied for the healing of postoperative wound healing disorders, severe burns, osteomyelitis or diabetic foot (Yan *et al*., 2018).

Advantages and Disadvantages of Maggot Debridement Therapy

Advantages:

The cost of using maggot therapy is relatively low. The therapy also accelerates healing of wounds and there is no need for anesthesia because the technique is painless (Jalal, *et al*., 2016). It does not kill the body's normal flora as systemic antibiotics do (Sherman, 2003).

Disadvantages

One important limitation to the application of maggot debridement therapy is that maggots can run away from the dressing. Maggots are not available in pharmaceutical stores; hence special expertise is required to breed maggots for the therapy or has to be ordered from specialists. Maggot therapy is however not suitable for all wounds, for example, it cannot be used in treating wounds in body cavities or in close proximity to large vessels (Nigam, 2021). The therapy may also cause irritation and itching to the patients at the wound site.

CONCLUSION

Maggot debridement therapy is a therapeutic wound management technique which involves the use of live larvae of certain fly species that feed on dead animal tissues. This therapy is a technological innovation from knowledge of myiasis. It came to limelight during the first World War when it was found that wounds of soldiers healed faster when it was naturally infested with maggots than otherwise. Studies then revealed that the maggots fed on the necrotic tissues only, hence preventing contamination of healthy ones.

The mechanisms by which maggots debride wounds and aid healing process have not been proven. However, a combination of mechanisms has been revealed through studies. It is believed that the crawling maggot stimulate living tissues in the wound to produce granulation tissues as well as liquefy necrotic tissues through enzymatic process. Maggots may also produce antibacterial agents that are released in their secretions.

The therapy has proven effective in the management of wounds especially deep and diabetic wounds, hence, its general adoption by healthcare practitioners involved in the management of wounds is advocated. However, there are some factors militating against the application of this therapy. These include; lack of awareness and knowledge about maggot debridement therapy by patients and clinicians, obtaining authorization to use the therapy in health facilities, paucity of suppliers of maggots for debridement and non-availability of the maggots for the therapy at the time of need. The therapy should be embraced in such a manner that medical laboratories would have a section responsible for breeding and supply of the maggots for use. Clinicians and patients should also be educated on maggot debridement therapy to break misconception about the therapy.

Author contributions

NIA and OBC carried out literature search. NIA prepared the original draft of the manuscript while EHC edited the draft of the manuscript. All authors read and approved the final copy.

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