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The Classic

Maggots in Treatment of Osteomyelitis: A Simple Inexpensive Method

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Dr. Duncan C. McKeever is shown. Figure is ©1960 by the Journal of Bone and Joint Surgery, Inc. and is reprinted with permission from Duncan Clark McKeever 1905–1959. *J Bone Joint Surg Am.* 1960;42:189–190.

Duncan Clark McKeever was born in rural Kansas in 1905 [5, 8, 9]. He attended local schools and having financed his own education (partly through the Naval Reserve) graduated from the University of Kansas Medical School in 1929. He interned at the Naval Hospital in Brooklyn, then was assigned to the Great Lakes Training Station in Chicago for three years. He returned to Kansas City to begin a residency in pathology, where he was inspired by the work of Drs. Frank Dickson and Rex Diveley (both of whom were early Presidents of the American Academy of Orthopaedic Surgeons [3, 4]) and subsequently studied orthopaedic surgery with them. He moved to Houston in 1939 to enter into private practice, but his practice was interrupted by the war, where he served at the Long Beach Naval Hospital and Area Hospital in Honolulu. He returned to private practice in 1945 and continued to be very active until the time of his death. His premature death occurred by a traffic accident: on a rainy day in October 1959, he had borrowed a car which ran out of gas and, as he was filling it, he was struck by another car and killed.

He was a man of great energy by all reports. In addition to his many publications and innovations, he served in leadership positions in a variety of professional organizations. He was a founding member of the Association of Bone and Joint Surgeons in 1947. His innovations include a patellar prosthesis first reported in 1955 [8] and a tibial plateau prosthesis reported in 1960 [9]. These sorts of innovations were forerunners of our contemporary joint implants.

The paper we reproduce here, however, describes the use of maggots to treat infection. McKeever [7] credits Baer [2] with the development of the approach in osteomyelitis based on observations Baer made in France during WWI. (Editor's note: The error in the referencing in this Classic between References 4 and 5 is in the original manuscript.) However, Baer noted previous writers (including the great French war surgeon and surgeon-in-chief to Napoleon's armies, Dominique Jean Larrey) had mentioned the beneficial effects of maggots in soft tissue wounds throughout the 1800s. Thus, the concept was well-known, if not widely used, and not specifically applied to chronic osteomyelitis. McKeever [7] describes in great detail the production of nonsterile maggots and how to apply them in chronic osteomyelitis. While the beneficial effects of maggots in wounds and in osteomyelitis in particular have been documented over the years, they have never gained widespread use. Nonetheless, the United States Food and Drug Administration approved the use of sterile maggots in 2004 [1]. As noted by McKeever, the method remains simple and

inexpensive, and appears effective [6, 7, 10]. The approach is one which could readily be used worldwide, particularly when antibiotics are not available or effective and when surgery is impractical.

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The use of maggots in the treatment of osteomyelitis has been widely popularized by the work of the late Dr. William S. Baer [1] and by the wave of publicity which followed his investigation. Those reporting the use of maggots have found the treatment very satisfactory, and their results compare favorably with those obtained by other well known procedures. If the use of maggots for this purpose is as beneficial as the reports indicate, a further investigation of technique may be valuable.

In reviewing the literature to date, one is dismayed by the difficulties, the expense, and the time involved in the methods described. At present it is impossible for a small hospital to provide its own supply of sterile maggots, as the expense for necessary equipment as described by Baer would run into hundreds of dollars, and the culture and handling of flies and maggots would necessitate the employment of a trained, full-time technician. Sterile maggots may be purchased at a quoted rate of five dollars per thousand. This number is sufficient for one ordinary application. The number of applications necessary varies in Baer's series from one to thirty-six, with an average of eleven; at a cost of five dollars per application, the cost of maggots alone would average fifty-five dollars per patient. This cost is an important item when added to the expense of the usual prolonged hospitalization of patients with osteomyelitis. Therefore, a simple, inexpensive method, by which maggot treatment may be made available to anyone, has been worked out and will be described.

When Baer began his work, he used unsterilized maggots successfully until two of his cases developed tetanus. He then devised his elaborate and costly method of producing sterile maggots. Nevertheless, a prophylactic injection of tetanus antitoxin for all patients being treated is still advised, as a precautionary measure, by the firm selling sterile maggots. Unsterile maggots are just as efficient as sterile maggots in their action on the lesion and, had Baer given prophylactic antitoxin, his two cases of tetanus would not have occurred. The only pathogenic organism present other than tetanus was the gas bacillus. Baer proved by controlled experiments on guinea pigs that maggots protect animals from gas-bacillus infection. No cases of gas gangrene have been reported, whether sterile or unsterile maggots were used. There is, then, no valid reason why sterile maggots are more effective or safer than unsterile maggots. Livingston [2] has used unsterile maggots extensively at the Hines Memorial Hospital and there have been no unfavorable results in a large series of cases recently reported by him. Weil and Nettrour [3, 7], Rohm [3], Goldstein [4], Wilson, Doan, and Miller [5], Thorek [6], Henry [7], and Sweadner [7] have also used both sterile and unsterile maggots; and their results have not been noticeably different from those reported by Baer.

Contrary to described methods, the culture of flies and raising of maggots is amazingly simple. Under almost any conditions flies will live, lay eggs, and grow maggots if sufficient suitable food is supplied. The ease with which they can be grown may be suspected if the adverse conditions

under which flies and maggots live and propagate in nature are considered. The varied conditions under which they may be grown make their controlled culture inexpensive.

In October, 1931, a supply of maggots was offered for use, in the treatment of osteomyelitis, on the service of Dr. Frank D. Dickson and Dr. Rex L. Diveley at St. Luke's Hospital. These maggots were raised on raw beef without any attempt at sterility. They were washed in a 1–1000 solution of bichlorid of mercury with twenty-five per cent. alcohol before introduction into the wound. Treatment of two cases of osteomyelitis of the hip was undertaken. Very little was known about keeping the maggots in the wounds and many escaped. Some of these were used as a stock supply and at present all our cases are treated with maggots descended from this stock.

There were no funds available for equipment,—such as incubators, cages, heating elements, thermostats, water-vapor controls, fans, etc., usually described as indispensable. A box of approximately eighteen by twenty-four by thirty inches was set on legs. Glass windows were fitted to the front. Two old thermostats from bacteriological incubators were reconditioned and installed, one being used as a safety unit. A 200-watt light was placed near the back of the box to supply heat. A pan of water was placed under it to provide moisture. No attempt was made to circulate the air. A small shelf was built in to hold the jars of maggots so they might be kept in the dark (Fig. 1). Any similar apparatus would be equally satisfactory. The temperature should be regulated from seventy to ninety degrees fahrenheit; the higher temperature promotes rapid growth of maggots but the flies live longer at the lower temperature.

The original stock of maggots was put on a piece of raw beef in a jar and in a few days reached adult size. Sand was poured on them and they crawled into it and formed pupae. These pupae were placed in a petri dish in a cage constructed as follows (Fig. 2): A flat box of a size that would easily fit in the incubator was secured. The top and bottom were replaced with screen wire and a small door placed in one end. The cage thus stands upright on one side of the box. The door should be at the bottom, as this prevents escape of flies when changing food and cleaning the cages. After about seven days, the pupae hatched to flies.

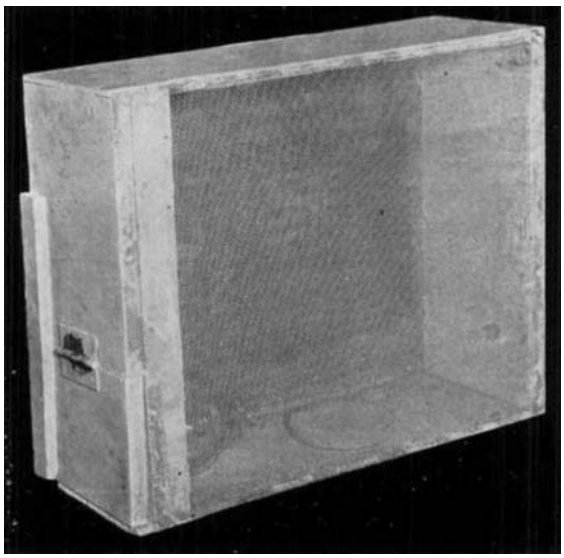


Fig. 2 Fly cage with a supply of food in place.

Flies are fed on a mixture of one ounce of honey, one dram of yeast powder, and eight ounces of water. This food is all the flies require. It should not be allowed to ferment and should be constantly present. The food was placed successively on cotton, sponge rubber, cloth, crackers, and in jars with wicks, but was found to require less attention when merely placed on a slice of bread in a petri dish. One such supply easily lasts forty-eight hours. About seven days after hatching, the flies are ready to lay and the eggs are most readily collected on a small bit of raw beef, measuring about one-half by one by one inches, which is placed in the cage on a bit of waxed paper. The eggs will hatch in eight hours or

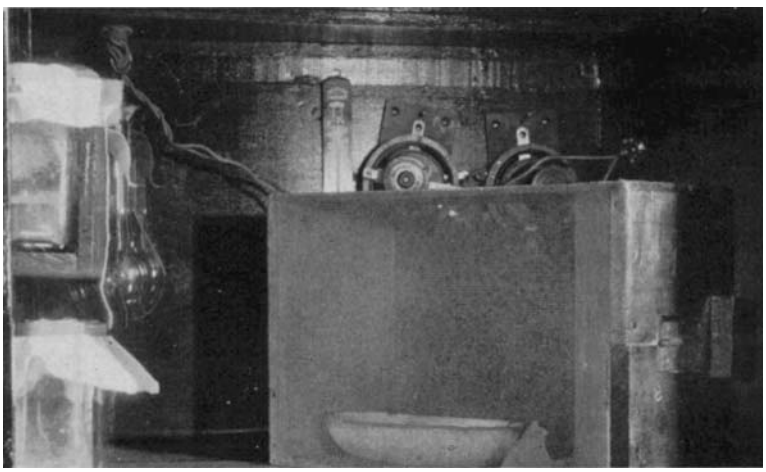


Fig. 1 Incubator showing thermostats, light to supply heat, pan for water, and shelf to shade maggots from the light.

less at incubator temperature and must be removed before hatching if they are to be transferred to other media for growth. Meat should be placed in the cage for a few hours about every second day, for the purpose of collecting eggs. Meat, as a possible source of pathogenic organisms, may be entirely eliminated. The flies will lay on almost anything after about seventy-two hours. A small piece of agar will suffice, or the eggs may even be collected from the bread on which the food is placed.

The media for culturing the maggots to proper size for use in treatment is prepared as follows: A circular hole is cut in the lid of an ordinary petrolagar jar. This hole should occupy almost the entire top. A piece of raw liver, about one inch in diameter, is put in and the jar filled to the level of the top of the liver with peptone agar to which yeast has been added in the proportion of about one cake to 1000 cubic centimeters. A single layer of old sheeting is placed over the top of the jar and the lid screwed in place over it. The jars are then autoclaved twice, with a twenty-four hour interval of incubation, and stored in an icebox until needed (Fig. 3A). This is one of the media used by Baer. It is the only one needed and is very satisfactory.

Eggs are transplanted to this media. This is best done with a toothpick or small scalpel kept for the purpose. Each fly will lay over 100 eggs at a time and about four to six such layings can be raised to the size required in a jar of media made as above. The jars are then incubated until the maggots are the proper size for use. The rate of growth depends on temperature and relative food supply, and usually forty-eight to seventy-two hours are necessary. At this time the maggots will be about onefourth inch long or slightly more (Fig. 3B). During this growth period, care must be taken to keep the cloth cover dry so that it will admit air. If it becomes wet, due to maggots crawling over it, the air is shut off, and the maggots die in as short a time as six to eight hours.

When the maggots have grown to the proper size, the jars may be placed directly in the icebox until needed; but it is much more convenient and time-saving if several jars of maggots are grown to the proper size at the same time and washed up ready for use before storing. The washed maggots will remain in good condition for a longer time than the unwashed ones. At first, considerable difficulty was found in separating the maggots from the media on which they were grown. However, it was noted that about twenty-five per cent. of them float in water and about forty per cent. float in normal saline. It was then only a step to the addition of about two tablespoonfuls of sugar to each jar after it had been nearly filled with water. When the proper amount of this is stirred into the solution, the maggots all float and leave the media in the bottom of the jar; but, if too much sugar is stirred in, particles of media also float. The maggots are then dipped into an ordinary tea strainer and are thoroughly rinsed with tap water and placed for thirty minutes in a 1–1000 solution of bichlorid of mercury with twenty-five per cent. of alcohol. They are then strained again and are ready for use. Placed in an empty media jar, they may be kept in good condition in an icebox for as long as two weeks (Fig. 3C). When needed, these maggots may be removed, rinsed with ice water, and implanted in the wound. When cold, the maggots are almost inactive and much easier to handle.

Each generation of flies will live and produce eggs for about four to six weeks. For replacing the flies, one laying of eggs may be grown to maturity, on a large piece of steak, in about seven days. If the usual media is used, three jars of it will be necessary to grow one “laying” of eggs to adult maggots. Large jars of media may be prepared for this purpose. When adult in size (about one-half to five-eighths of an inch long), the maggots are transferred to dry sand and will pupate in about forty-eight hours. Maggots will also pupate in a wad of dry gauze. Pupae may

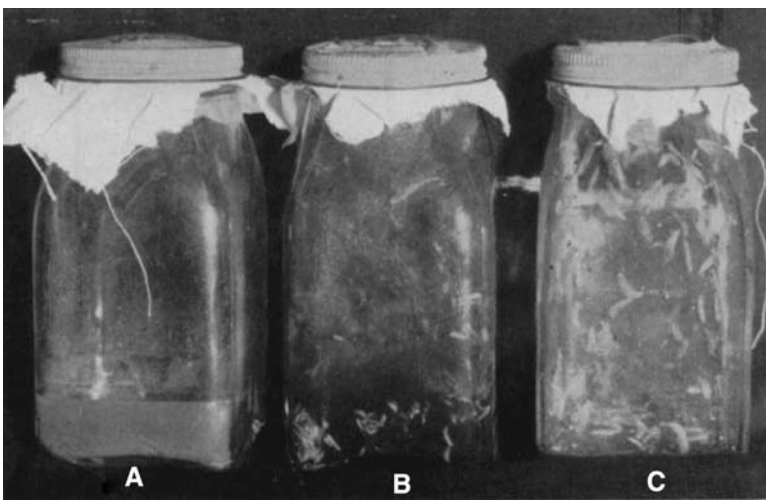


Fig. 3 (A) Fresh jar of media. (B) Jar of media containing maggots forty-eight hours old. (C) Maggots washed and ready for use or storing.

be kept on ice, with only a small percentage of loss, from two to three weeks, possibly longer, before being placed in the incubator for hatching.

Technique of Implanting Maggots

In implanting the maggots and keeping them in the wound, there are several procedures which have been found useful. It is not necessary to the success of the treatment that all the maggots be kept in the wound, and one worker who has used them in a large number of institutional cases makes no effort to keep them in. However, it is very imperative, in private practice, that the patient be kept comfortable or he will not submit to the treatment. If the maggots are strictly confined to the wound, the patient has no discomfort unless there are nerves exposed. If this is the case, the pain can be controlled with sedatives and will usually disappear after the second application. I find bromid and codein the most useful drugs.

The most important single consideration in keeping the maggots in the wound is the maintenance of adequate drainage in some way, so that the maggots can not escape by the same route. It is obvious that those maggots which escape the confines of the wound are useless therapeutically, and they cause constant annoyance to the patient. The only method which I have found satisfactory for keeping the maggots in the wound consists of placing a close-fitting, screened cage over the wound and taping it down tightly. This is not always effective but, with a little experience in application, the device will become about ninety-five per cent. efficient.

The screened cage is made by cutting a piece of 60-mesh milk-strainer wire (cost forty cents per square foot) to a size about one-fourth of an inch larger than the edge of the wound (Fig. 4A). This may be done from a pattern, but a little experience will enable one to cut them without. A strip of sponge rubber of soft texture and about one-half inch thick is cut. This should be about one-half inch wide and a little longer than the circumference of the screen. It is folded over the edge of the screen and sewed in place with a close stitch drawn tightly (Fig. 4B). Satisfactory screens may also be made by sewing edges of the milk-strainer wire between two strips of sponge rubber or inlaying it in a window in a flat piece of sponge rubber and sewing it in place. These screens may be sterilized by boiling, but should be dry at the time of application.

The screens are applied in much the same manner as described by Child and Roberts [8]. The surrounding skin is cleaned with ether and a layer of flamed adhesive is applied to the edge of the wound. This is coated with liquid adhesive. The maggots are then put in the wound and covered with the screen cage which is tightly taped down, leaving the screen exposed. The tape should be applied in the manner of a basket splint in order to make pressure around the wound. If the screen is large, a narrow strip of adhesive may be drawn across the top to hold it firmly in place. If on an extremity, a snug bandage should be applied to hold the tape in place (Fig. 5). A pad is so placed as to catch the drainage from the wound but not to obstruct the access of light and air to the screen. The bandage and pad may be changed as often as necessary without disturbing the remainder of the dressing. The maggots are left in the wound for five days at each application, unless there is some indication for their removal at an earlier stage. If the drainage stops, the maggots are probably dead and should be removed, although the wounds do well even when the maggots are dead. Using a support for bed covers, a light may be placed to shine on the screen. The light drives the maggots deep into the wound and adds to the comfort of the patient. It should not be placed so close as to dry the secretions on the screen as this blocks drainage and results in quick death of the maggots. Between applications of

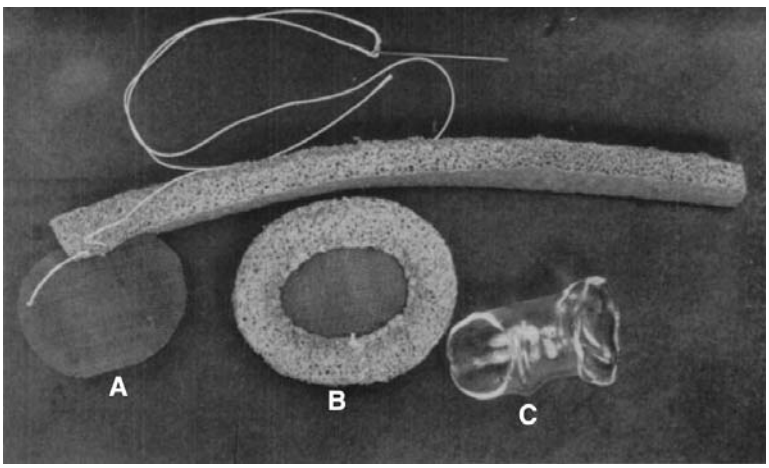


Fig. 4 (A) Method of edging screen with sponge rubber. (B) Completed screen. (C) Glass tube to be used in wound to allow drainage and prevent too early closing of the skin edges.

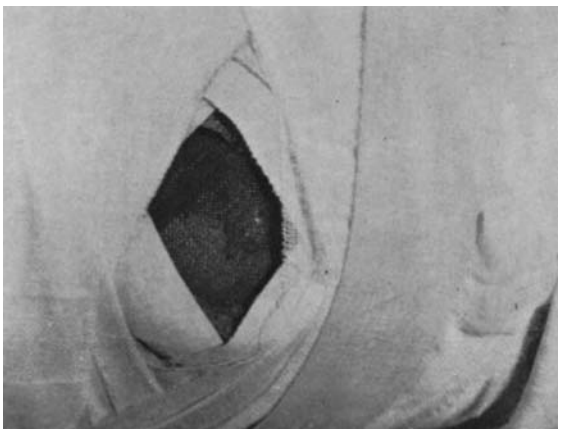


Fig. 5 Complete dressing on an extremity, showing screen held in place by adhesive and bandage.

maggots, a day's rest is given, the wound being tightly packed with dry gauze.

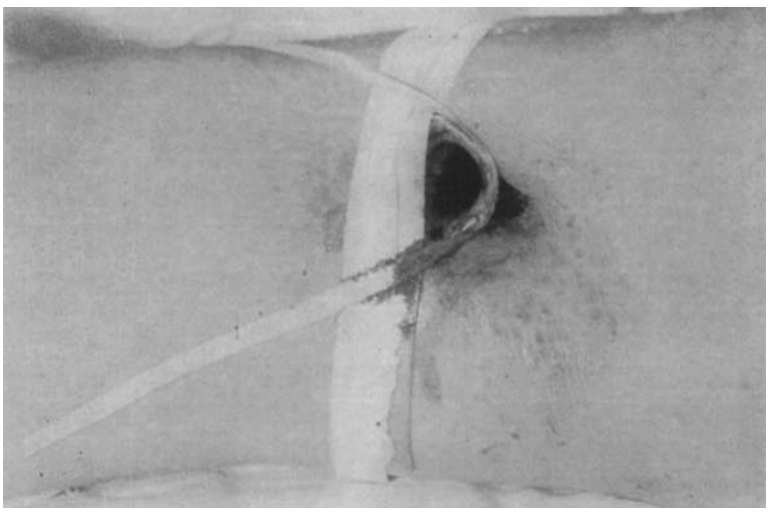
In all cases, there is a great tendency of the wounds to heal at the outer edges. Often, if the outside opening is not particularly large, the wound will nearly close at the surface during one period of maggot treatment. In this case, a small glass tube about one-half inch in diameter and long enough to go nearly to the bone may be used (Fig. 4C). The maggots then have access to the depths of the wound and good drainage is maintained. As the wound heals, a shorter tube may be used. The tube should be held in place with adhesive strips (Fig. 6). The usual dressing is applied over the wound.

Some workers report that the maggots live only a few hours in the wound after the first application and believe this is due to some substance secreted in the wound by the body or to some substance resulting from the maggots' own metabolism. It does not seem logical that the maggots would themselves produce a substance which would result in their death, and in nature maggots live to maturity in open wounds on live animals. I am of the opinion that, if the maggots die, it is a result of inadequate drainage. In culture, they die if too much moisture is present and if air is excluded. We have cases which have had many applications, in which the maggots live five days if good aeration and drainage are maintained. The progress of these cases is as satisfactory as any in which maggots have been used. I have seen the dressings of one worker who makes no effort to keep the maggots in the wound and merely covers the wound with a large gauze dressing. This dressing rapidly becomes soaked with secretion and it would be remarkable if the maggots did live long under it.

The usual advice is to completely fill the wound with maggots. This usually results in death of many of the maggots in a few hours because the drainage is blocked. If the maggots do live, they grow and crowd off the screen and escape, causing the patient great discomfort. I try to put in a number which I think will approximately fill the wound when they are at the adult stage of growth. This is about one-fourth to one-third of the wound volume when the maggots are at the three-day stage. The maggots rapidly seek out and devour all available food and continue working for a full five days.

After the bone is completely covered with granulations, the question of secondary closure of the wound arises. If the maggot treatment is continued, the wounds will eventually heal to skin level; and, in cases with only local bone involvement and a small wound, this is perfectly satisfactory and healing may be completed in as short a time as four weeks. In cases with extensive bone involvement and a wide incision, the healing is progressively slower and, near the end, may be completely arrested. One worker recently told me that the greatest difficulty was encountered in the final stages of healing of the soft tissues. If the wound does heal, the resulting scar is wide and thick, the circulation

Fig. 6 Glass tube to maintain surface opening of wound, held in place by adhesive.



rapidly becomes poor, and, if subjected to trauma, it may break down. If secondary closure is done after all bone is healed over, the formation of a large mass of scar tissue is avoided, and the wound closes rapidly and with a much better cosmetic result. Certainly, the course of the treatment is greatly shortened and subsequent breakdowns in the soft tissues are less likely to occur. It is not necessary to prepare the wound for closure other than to cleanse it with saline irrigations. If thought advisable, the wound may be dakinized or cleansed otherwise. In one case, we removed maggots and closed the wound on the second day thereafter. It remained closed after a few days of slight drainage. Like most secondary closures, these wounds usually partly break down and then heal rapidly.

Summary

1. A method is presented by which maggots may be raised for use in a hospital or private practice.
2. Very little time is required in culture and growth of maggots by this method.
3. The expense for equipment is almost negligible since most of the apparatus is home-made.
4. If the maggots are properly applied, any slight discomfort to the patient is easily controlled.
5. If proper drainage is maintained, the maggots do not die in the wound.
6. Secondary closure of the wounds, after the bone is covered with granulation tissue, is advisable if the wounds are extensive or in a position exposed to trauma.

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