

Role of Suture Materials in the Development of Wound Infection

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THE SEARCH for an ideal suture material suitable for all purposes has been pursued by surgeons since the time of Paré. None has been found, however, and despite numerous investigations concerning tissue reaction, handling qualities, holding strength, etc., surprisingly little has been written concerning the ability of various types of suture material commonly in use to resist bacterial infection after their introduction into contaminated wounds.

Several investigators have compared the incidence of infection in wounds closed with various suture materials both experimentally and clinically. Halsted,⁵ in 1913, expressed a strong preference for the use of silk in clean surgical wounds, but stated that it should be avoided in contaminated or infected ones. Whipple,⁸ in 1933, strongly advocated the use of silk in repair of clean wounds, indicating that the incidence of infection was actually less than when chromicized catgut was used. In 1937, Shambaugh and Dunphy⁷ studied the comparative incidence of infection in contaminated wounds closed with silk or with chromicized catgut in dogs. The wounds were contaminated either with feces or an uncounted staphylococcal culture. They found that infection actually occurred less frequently with silk than with catgut, and there was little problem with extrusion of the silk. In 1940, Elkin⁴ published a clinical study which compared the incidence of

infection between silk and catgut in both clean and potentially infected cases. Infection occurred considerably more frequently in the catgut group than in the silk group in both categories. It was not stated whether chromic catgut or plain catgut was used in that particular study. Nonetheless, the methods of preparation and sterilization of catgut materials have changed considerably since that time, leaving some doubt about the present-day application of these studies. James and MacLeod⁶ performed a more complete study in 1961, implanting small pieces of contaminated suture material subcutaneously into mice. Although their problems included extrusion of suture material and only fair quantitation of the numbers of viable organisms introduced, much significant information was obtained. Their experiments indicated that silicone-treated silk was similar to untreated silk in the ability to withstand contamination and that cotton and merseline sutures resembled silk. Nylon, however, withstood contamination somewhat better than the other materials tested. Catgut and steel wire could not be evaluated because of the problem of extrusion. They concluded that the degree of enhancement of infection by the suture material roughly paralleled the inflammatory reaction caused by the suture material itself.

Elek and Conen,³ in their studies with normal human subjects observed that approximately 1,000,000 staphylococci were

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necessary to cause an infection when introduced by intradermal injection or into a simple wound, but when the organisms were introduced with a silk suture, which was placed subcutaneously, as few as 100 organisms could initiate an infection. During experiments in our own laboratory of the effectiveness of prophylactic penicillin therapy in contaminated wounds,¹ it was noted that the majority of infections began around suture materials left within the wound.

Thus, there is good evidence that the suture material itself may contribute greatly in the genesis of wound infections. The studies reported herein were performed to make a comparison among several types of suture material commonly in use in their ability to resist contamination when introduced into small wounds which were contaminated with controlled numbers of staphylococci.

Materials and Methods

Multiple small wounds, 9 to 16 in number, were made on the abdominal walls of domestic rabbits with a #11 knife blade after aseptic preparation of the shaved abdomen by scrubbing with soap and water and swabbing it with 70 per cent alcohol. Small subcutaneous pockets were made with curved iris scissors in the layer between the skin and panniculus carnosus, and standard bits of suture material were placed within these pockets. The small wounds, which were approximately 3 mm. in length, were then sealed by the application of collodion to the opposed margins. In this manner, a number of standardized pieces of suture material could be implanted within individual small wounds on the abdominal wall of a single animal, thus allowing comparison of the incidence of infection without concern for deviation in host resistance from animal to animal. Bacterial inoculations were made from serial ten-fold dilutions in physiological saline of an 18-hour brain-heart infusion broth cul-

ture of a single strain of hemolytic coagulase positive *Staphylococcus aureus*, phage type 29,52, which previously had been proved pathogenic for rabbits. It was found that the most satisfactory way to assure a uniform degree of contamination was by injection of 0.05 cc. of a suspension of staphylococci directly onto the suture using a #30 hypodermic needle after the wound had been sealed with collodion. By using the same suspension for all inoculations during a given experiment, uniform numbers of organisms could be introduced onto the different suture materials implanted in the wounds which were to be compared.

The animals were individually caged following inoculation and given food and water *ad lib.* until the time of sacrifice five or six days later. Longer periods of observation resulted in drainage of abscess pockets with extrusion of the suture material, while shorter periods of observation sometimes failed to result in the development of mature lesions. All sites of inoculation were carefully examined at the time of sacrifice for evidence of infection, and the lesions were graded according to the severity of infection. Lesions without pus formation were read as zero; 1⁺ represented a collection of pus measuring less than 2 mm. in diameter; 2⁺ represented a collection measuring 2–5 mm. in diameter; 3⁺ represented a collection measuring 5–10 mm. in diameter; and 4⁺ represented a collection of more than 10 mm. in diameter. Random cultures of the abscesses during the course of the experiments showed that the infections consistently resulted from the organism used for inoculation. Differences in the degree of infection among suture materials were recorded for each animal, and these were subjected to statistical analysis using a *t* test.²

Experiment I. A comparison was made among three types of braided, dyed silk (waxed, siliconized, and untreated), and untreated, machine-twist, white silk. Size 0000 suture material was used throughout

this experiment; the standard suture consisted of a piece containing six knots which had been tied over a 20-gauge needle. Three pieces of each type suture were implanted in the abdominal wall of each of 12 rabbits, and one of each type was inoculated with a full strength broth culture and dilutions of 10^{-1} and 10^{-2} .

Experiment II. Comparisons were made among size 00 monofilament nylon, size 00 braided nylon, size 00 monofilament wire, and size 00 twisted wire (Flexon). Pieces of suture containing three knots were placed in separate wounds on the abdominal walls of 12 animals, and inoculations were made with 10^{-1} , 10^{-2} , and 10^{-3} dilutions of the standard culture.

Experiment III. Chromic catgut, plain catgut, and iodized catgut were compared in this group of 12 animals. Each piece of suture material consisted of four knots of size 000 suture tied over a 20-gauge needle. Inoculations were made with 10^{-1} , 10^{-2} , and 10^{-3} dilutions of the standard culture.

Experiment IV. Black, braided, waxed silk, chromicized catgut, white-twisted surgical cotton, and black-braided nylon were

compared in this group of 12 animals. Standard pieces of suture material consisted of three knots of size 00 suture tied over a 20-gauge needle. Inoculations were made with full-strength broth culture and dilutions of 10^{-1} , 10^{-2} , and 10^{-3} .

Experiment V. Braided waxed silk, iodized catgut, twisted steel wire (Flexon), and blue linear polyethylene (Marlex) were compared in this group of 12 animals. Standard suture material consisted of size 000 suture containing three knots tied over a 20-gauge needle. Inoculations were made with 10^{-1} , 10^{-2} , and 10^{-3} dilutions of the standard broth culture.

Experiment VI. Comparison was made among braided waxed silk and chromicized catgut in 12 animals. Standard pieces of suture material were prepared by tying three knots of size 00 suture over a 20-gauge needle. Inoculations were made with full-strength broth culture and dilutions of 10^{-1} and 10^{-2} .

Results

The average degree of infection for each strength of inoculum in each of the experi-

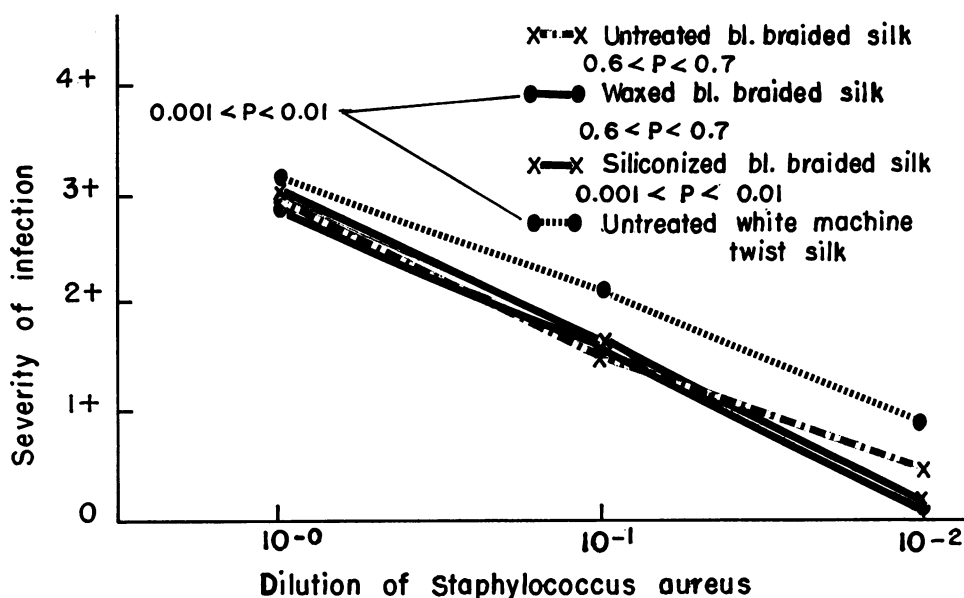


FIG. 1. Comparison of untreated black braided silk, waxed black braided silk, siliconized black braided silk, and untreated white machine-twist silk.

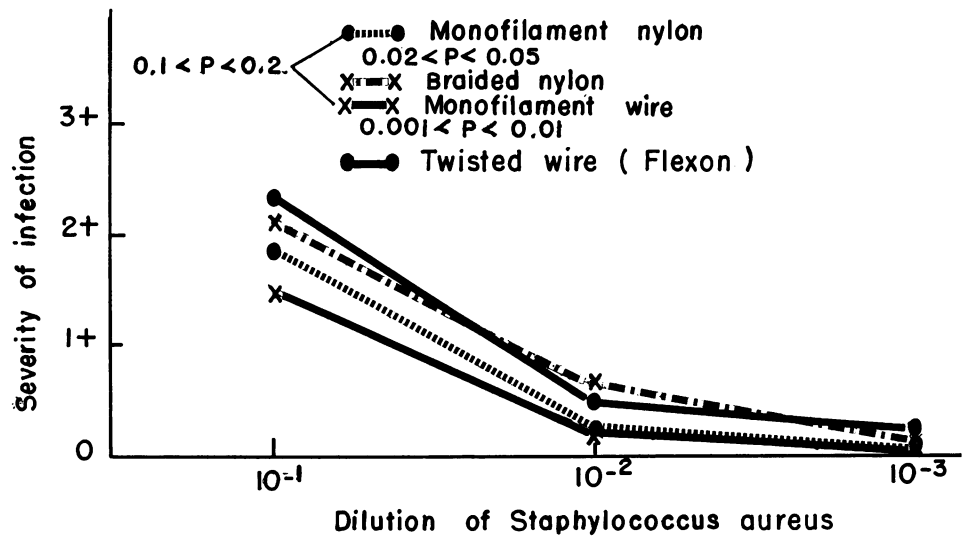


FIG. 2. Comparison of monofilament nylon, braided nylon, monofilament wire, and multifilament twisted wire.

ments was determined and is graphically represented in the figures. When obvious differences occurred between the curves for different suture materials, the statistical probability of the difference was determined. The results of these analyses are also given in the figures.

Experiment I. Figure 1 shows the average degree of infection resulting from con-

tamination of four types of silk. There was no significant difference in the degree of infection among waxed silk, siliconized silk, and untreated braided silk, but untreated, white, machine-twist silk resulted in significantly more severe infection ($0.001 < p < 0.01$).

Experiment II. Figure 2 shows the average severity of infection in the compari-

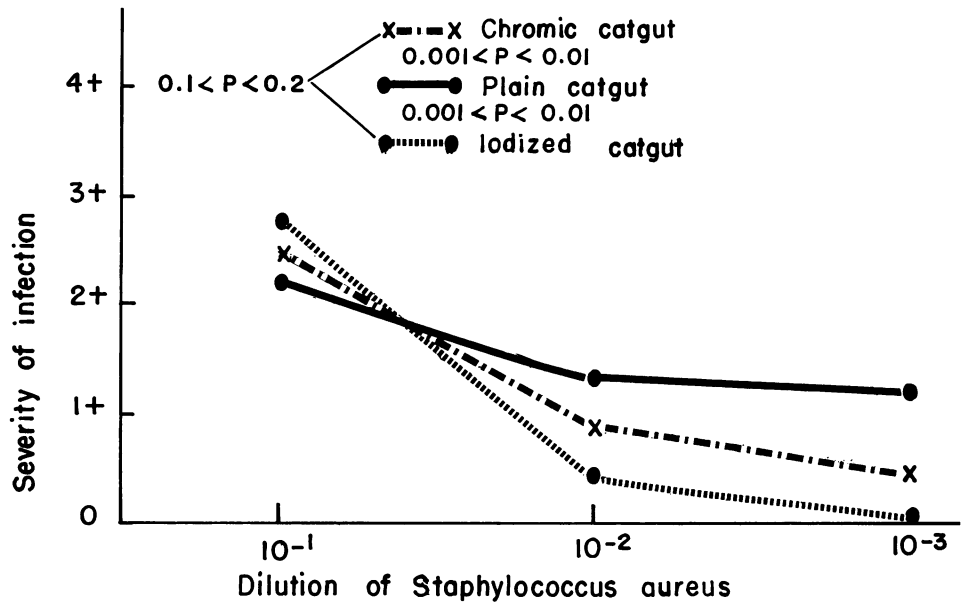


FIG. 3. Comparison of chromicized catgut, plain catgut, and iodized catgut.

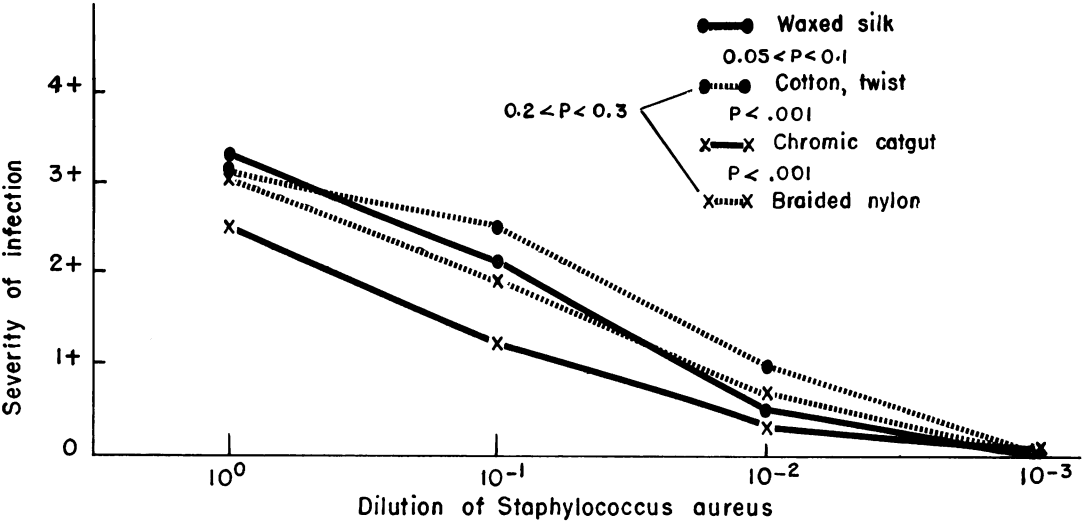


FIG. 4. Comparison of black braided waxed silk, chromicized catgut, white twisted surgical cotton, and black braided nylon.

son of monofilament nylon, braided nylon, monofilament wire, and multifilament twisted wire. There was no significant difference between the monofilament nylon and monofilament wire, although the wire had slightly less infection ($0.1 < p < 0.2$). Appreciably more infection resulted when these materials were implanted in a braided ($0.02 < p < 0.05$) or twisted multifilament

form ($0.001 < p < 0.01$) with the same number of organisms.

Experiment III. Figure 3 shows the average severity of infection in the experiment comparing chromic catgut, plain catgut, and iodized catgut. Iodized catgut resisted infection slightly better than chromic catgut, but not significantly ($0.1 < p < 0.2$). Iodized catgut and chromicized catgut

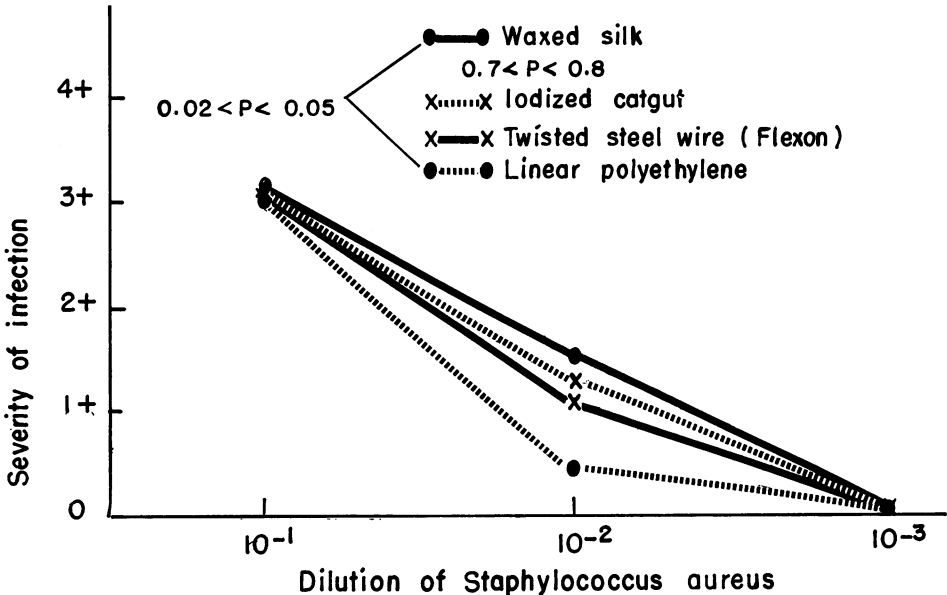


FIG. 5. Comparison of braided waxed silk, iodized catgut, twisted steel wire, and blue linear polyethylene.

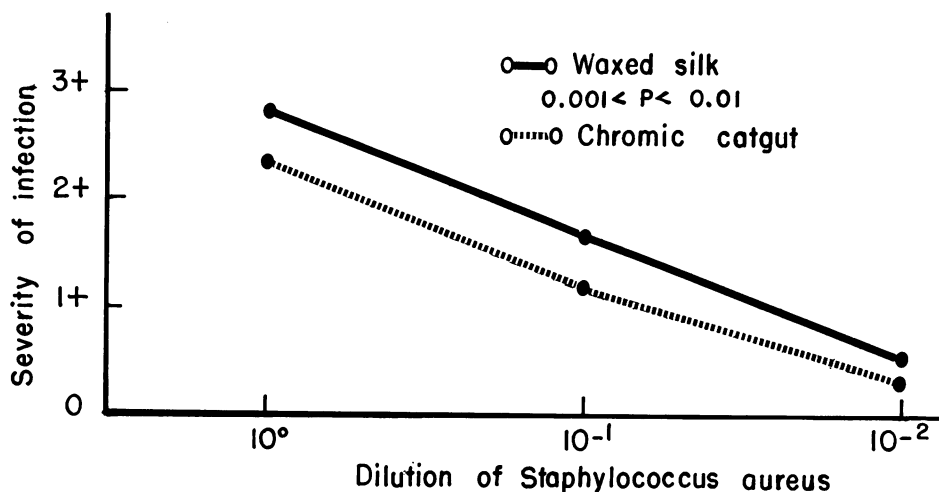


FIG. 6. Comparison of braided waxed silk and chromicized catgut.

both resisted contamination considerably better than did plain catgut ($0.001 < p < 0.01$). Relatively severe infections were seen with the latter with the 10^{-3} dilutions.

Experiment IV. The average severity of infection in the comparison of braided waxed silk, twisted surgical cotton, chromicized catgut, and braided nylon are shown in Figure 4. The variation in susceptibility to infection of the nonabsorbable materials was insignificant in this group, but chromicized catgut resisted contamination significantly better than any of the nonabsorbable sutures ($p < 0.001$).

Experiment V. Figure 5 gives the average severity of infection in the comparison among braided waxed silk, iodized catgut, twisted multifilament wire, and blue linear polyethylene. Only the linear polyethylene resisted contamination significantly better than the others ($0.02 < p < 0.05$).

Experiment VI. This comparison between waxed silk and chromicized catgut again shows that the chromicized catgut can withstand contamination more readily (Fig. 6) ($0.001 < p < 0.01$).

Discussion

The development of postoperative and post-traumatic wound infections continues to be a complex problem of considerable

importance to both the surgeon and patient. Elek and Conen³ have shown experimentally that the introduction of staphylococci on a silk suture placed in the subcutaneous tissue can enhance the development of infection as much as 10,000 fold. It is obvious that the type of suture material used for closure of contaminated wounds might be of considerable importance in the development of subsequent wound infection.

The protocol used for this experiment was adopted because of several distinct advantages. While the small, surgically made, pockets are not equivalent to major surgical incisions, they could be made of comparable depth, avoiding the complexities of varying resistance between different types of tissues. Several kinds of suture material could be compared in a single animal using different strengths of the same bacterial inoculum. The numbers of organisms introduced onto the suture material were constant from one injection to another since the same broth culture was used, and the numbers of organisms changed only with a change in the volume of the inoculum. Likewise, pathogenicity and viability of the organisms were constant during the course of each single experiment. By determining the difference in infection among

the various suture materials on each single animal, a valid statistical comparison could be made using a relatively small number of animals.

In Experiment I, four types of multifilament silk suture materials were compared. No real difference in the degree or amount of infection was apparent when dyed, waxed, braided silk was compared with dyed, siliconized, braided silk or with dyed, untreated, braided silk, but all of these were associated with less infection than was seen with the white machine-twist silk which had a looser arrangement of the fibers. It thus appears that braiding of the silk suture material into more compactly placed strands is more beneficial than treatment with wax or silicone. Monofilament nylon and wire suture materials withstood contamination considerably better than either the braided form or the twisted form. A comparison of several other nonabsorbable suture materials, namely, braided waxed silk and twisted steel wire in Experiment V, and braided waxed silk, braided nylon, and twisted surgical cotton in Experiment IV, showed no significant difference in the incidence of infection among these materials. It would appear from these findings that nonabsorbable suture materials in a multifilament or braided form do not differ materially in their ability to withstand contamination, but when the same suture materials are made into monofilament forms, the resistance to contamination is improved. Blue linear polyethylene, when compared with braided waxed silk and twisted steel wire, also withstood contamination more readily. A comparison between braided waxed silk and chromicized catgut was made in 24 animals, and the chromicized catgut withstood contamination significantly better ($0.001 < p < 0.01$). When three types of catgut material were compared (chromicized, iodized, and plain), it was found that iodized catgut withstood contamination best, but not significantly better than chromicized

catgut ($0.1 < p < 0.2$). Both, however, withstood bacterial contamination much better than plain catgut ($0.001 < p < 0.01$).

In all of the experiments, monofilament suture material withstood contamination better than the same kind of multifilament material. Perhaps the bacteria were better able to maintain a defense against phagocytic activity once they had gained entrance to the interstices of a multifilament suture. There was no significant difference among the various types of multifilament nonabsorbable suture material in their ability to withstand contamination. Chromic catgut, a monofilament material, withstood contamination better than braided waxed silk, but not to a degree which was greater than that seen between monofilament and multifilament suture materials of the same composition. Treatment of the multifilament type of suture material to make a closer weave did seem to decrease the incidence and severity of infection following contamination.

It would appear from the results of these experiments that the use of monofilament material of practically any type is preferable to the use of multifilament suture material in contaminated wounds. It must be emphasized, however, that these experiments compared only the ability of these suture materials to resist contamination early in the postoperative course. The development of delayed infection was not evaluated, nor was the association of extrusion of suture material or sinus formation taken into account. Furthermore, the strength of suture material necessary in certain contaminated wounds or incisions might make a great difference in the choice of a suture material for closure of contaminated wounds in a clinical situation.

Summary

A comparison has been made of several commonly used types of suture material in

their ability to resist the development of infection in wounds which were contaminated with a single strain of virulent *Staphylococcus aureus*. Other virtues or disadvantages of these same suture materials were not the object of this study. The use of several types of suture material and at least three strengths of bacterial inocula in the same animal allowed comparisons which could be evaluated statistically.

There was no significant difference in the degree of infection which occurred with any of the nonabsorbable multifilament suture materials tested, these being braided siliconized silk, braided waxed silk, braided untreated silk, braided nylon, twisted steel wire, and machine-twist surgical cotton. Braided silk suture material withstood contamination slightly better than a type of machine-twist silk which had a rather loose arrangement of the fibers. Monofilament sutures withstood contamination better than multifilament sutures made of the same material. Both chromicized catgut and iodized catgut withstood contamination better than plain catgut, but the difference between iodized catgut and chromicized catgut was not statistically significant.

It would appear from these experimental studies that the use of multifilament suture materials and plain catgut should be avoided in wounds having known gross bacterial contamination. The development of wound infection in such instances could

best be prevented by the use of monofilament sutures, the type of which would be dictated by clinical circumstances.

Acknowledgments

Suture materials used were as follows: The machine-twist white silk used was commercially available as Belding, Corticelli, Buttonhole and button silk, shade 2300. All other silk sutures, cotton sutures, polyethylene sutures, nylon sutures, and wire sutures were supplied by the American Cyanamid Company. The iodized catgut suture was supplied by C. De Witt Lukens Company. The chromicized catgut and plain catgut sutures were supplied by Ethicon, Inc., and the American Cyanamid Company.

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