THREE YEARS' EXPERIENCE WITH VITALLIUM IN BONE SURGERY*

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IN OCTOBER, 1936, we[1] first described the effects of electrolysis on metals in bone and showed by our research that electrolysis was the principal cause of failure of metal appliances in bone. While conducting these experiments, we found only one alloy among all those tested that was completely passive (electrically inert) in the presence of body fluids, that caused no pathologic changes in bone, and that was not itself corroded. This alloy, Vitallium, composed of cobalt, chromium, and molybdenum seemed so inert that we recommended its use in bone surgery. Since then, Vitallium appliances have been widely used over a sufficient period of time to justify a statistical study of the value of this new alloy. Sixty-one surgeons in various parts of the country who have used Vitallium appliances cooperated with us in the following analysis which is based on a total of 1,227 cases.

These 1,227 cases do not include more than 200 patients in whom Vitallium hip cups have been used, or those instances where Vitallium orbital implants were utilized, but are those in which nails, screws, plates, *etc.*, were placed in bone to treat various fractures. For fractures of the neck of the femur, 23 surgeons used Vitallium Smith-Petersen nails, two used hip screws, two used lag screws, and three used plain Vitallium nails, without a single case of extrusion of the nails. The 1,227 fractures treated with Vitallium appliances included fresh fractures, old fractures with delayed or nonunion, compound fractures, and old cases where Vitallium screws were used to secure bone grafts. In all these varying conditions, and in the hands of many surgeons, 1,136, or 92.6 per cent of the cases, obtained solid bony union while 47, or 3.8 per cent, had delayed union, and only 44, or 3.6 per cent, developed nonunion. Many of these cases were those wherein there was much trauma or where the fractures were originally compounded.

Vitallium, of course, has no stimulative effect on the healing of bone but it is distinctive among metals in that it has no retarding effect. With such an absolutely nonelectrolytic alloy, it is possible to plate certain fractures or nail fragments securely without fear of erosion of bone about the metal appliances. The permanent immobilization of fragments which can be gained with this inert material insures rapid and solid healing of fractures. Metal nails in the hip have completely revolutionized the outlook for patients with fractures of the neck of the femur and the possibility of union is much greater when

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there is no erosion of bone about the metal (Fig. 1). Similarly, metal plates are invaluable in other troublesome fractures such as those in both bones of the forearm, the shaft of the humerus, or the upper end of the shaft of the femur.

For years, there has been much apprehension about the use of metal appliances in fractures because surgeons have observed many failures after they have placed highly electrolytic alloys in the bone. The subsequent electrolytic destruction of metal and bone caused the operations to end unsuccessfully and convinced the surgeons that metals cannot be used in the body with any degree of safety. Loosening of appliances, discoloration of tissues, and accumulations of sterile fluid caused by "electrolytic osteitis" were attributed to infection, faulty technic, or some vague foreign body irritation.

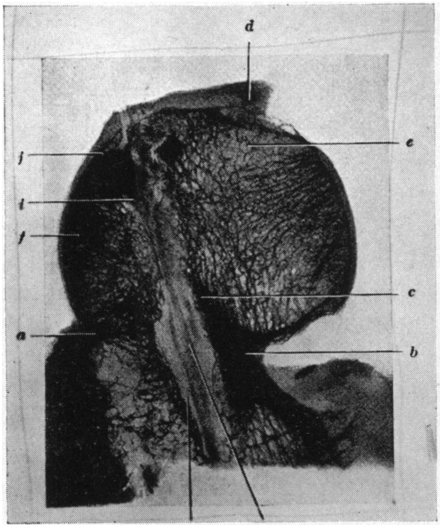


FIG. 1.—Photograph of neck of the femur where a stainless steel nail has been in the bone about eight months. Note deposits of metal in the head of the bone and absorption of cancellous bone along the path of the nail. (From Felsenreich: Arch. f. klin. Chir., 195, 30, 1939.)

Failures with Vitallium Appliances.—The original dental Vitallium alloy, with which we first experimented, was found to be too brittle and weak for fracture work. Shortly after we recommended its use in surgery, other surgeons also complained of the same defects in the material. Consequently, at our suggestion, the manufacturers of Vitallium modified the structure of the alloy to give it strength and toughness while retaining its remarkable passivity in body fluids.

Even so, for all the early cases with broken plates and screws, they constitute but a very small per cent of the successes with Vitallium appliances. Out of 1,227 cases, of all types, there were 11 instances in which a plate broke, or 0.089 per cent of the total. Ten screws broke, or 0.081 per cent of the total. Four plates bent, or 0.033 per cent of the total. Two nails bent, or 0.016 per cent of the total. One hip screw bent, or 0.008 per cent of the total. In other words, 1,199 of the cases, or 97.7 per cent of the total, had no technical trouble from the application of the metal.

Bent or Broken Plates.—In 1937, the first year Vitallium was generally used, several surgeons found that plates bent or broke even though the extremity was well supported externally. In these instances, the metal was at fault because it was too brittle at the outset. Also, the early flat plates were made too light and the Lane-type plates were too narrow. This has now been corrected by making heavier appliances of Vitallium more malleable, so that plates may be bent to fit an irregular surface without danger of breaking and they will not bend or break if an extremity is handled with reasonable caution.

Of course, no Vitallium or any other metal plate is strong enough to immobilize a fractured long bone without additional external support by plaster encasement or splint. Unless adjacent joints are immobilized by such splints, there is always the possibility that the fragments may move or that some undue strain will detach the appliance from the bone. The tensile strength of a nail, screw, or plate is not an important factor since it is only called upon to hold bone fragments together in normal alignment. The support of the entire extremity and the protection against muscle pull must be provided by plaster encasements and splints in addition to the plates attached to the bone.

Screws which erode bone by "electrolytic osteitis" are like screws in decaying wood that lose their hold and thus fail in their purpose. Just as it is important to keep screws and wood dry to prevent loosening, so is it necessary that screws in bone must be nonelectrolytic to prevent erosion of bone. Consequently, no metal plates and screws are absolutely dependable for immobilizing fractures unless they are totally passive (nonelectrolytic) in the body.

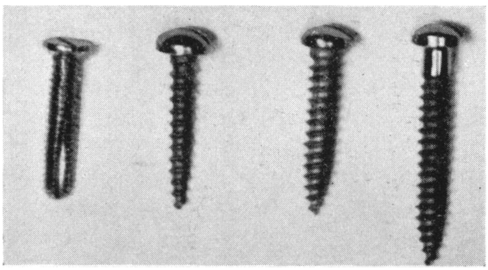


FIG. 2.—Photograph of various types of Vitallium screws. (Machine-type screw which cuts its own thread in the bone. First wood-type screw with too small a shank. Newer wood-type screw with threads to the head for use with plate. Wood-type screw with smooth shank for tightening fragments.)

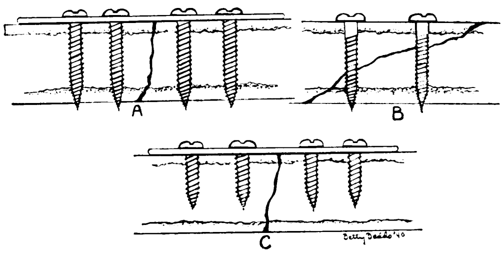


FIG. 3.—Diagram of bone with plate and screws inserted. (A) Long screws engaging both cortices giving best support. (B) Screws with unthreaded shank used to pull oblique fracture together. (C) Short screws engaging only one cortex.

Vitallium is so hard that plates, nails, and screws must be cast and this process is costly. Its strength is not as great as some of the stainless steels but it possesses, in its present composition, all the strength needed to immobilize bone fragments which are properly supported externally. Certainly, an alloy which is absolutely passive, and hence nonirritative, and which can be used by many surgeons with 97.7 per cent success, fulfills the requirements of an almost perfect material for the internal fixation of fractures.

Bent or Broken Screws.—The first Vitallium wood-type screws were made with a thin shank which was too fragile and which broke quite easily (Fig. 2). This has been corrected by making a heavier screw of tougher metal and with a stronger shank. The screws with threads which extended to the head were designed for use with a plate, while those in which part of the shank was unthreaded were made for pulling fragments together. Naturally, if the former type of screw is used for this purpose the drill-hole in the proximal fragment must be larger than the diameter of the thread. Improper screws or those used incorrectly would naturally tend to break (Fig. 3).

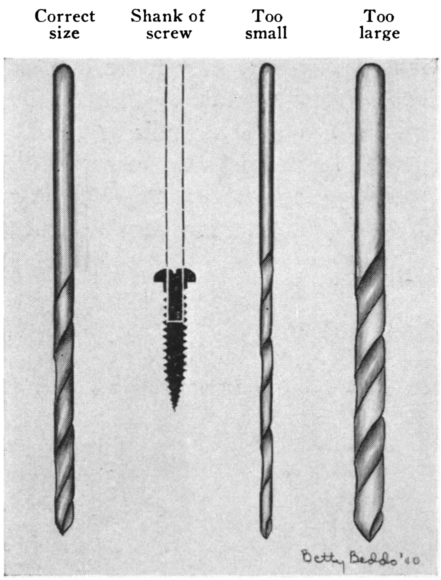


FIG. 4.—Diagram demonstrating correct size of drill to use in making screw-hole. Drill must be exact diameter of the shank of the screw.

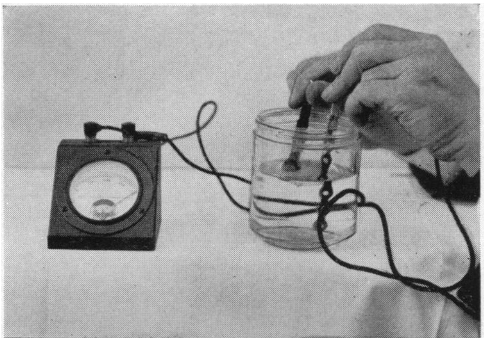
Many surgeons complained of difficulty in using the machine-type screws with the cutting edge which is supposed to make a path for the thread in the bone. When such a screw is cast of Vitallium, the thread is not sufficiently sharp to cut the bone easily. Also, such screws, without a taper point, are difficult to insert. Therefore, we feel that the machine-type screw of Vitallium is not nearly so successful as the plain wood-type or coach-type screw.

A rather obvious cause of failure in placing screws in the bone is disproportion between the size of the screws and the caliber of the hole in the bone (Fig. 4). The drill-hole should have exactly the same diameter as the shank of the screw. If the hole is larger than the shank, the threads do not engage deeply enough in the bone to secure a good purchase and the threads are easily stripped when the screw is finally tightened. If the hole is smaller than the shank, great force is required to drive the screw home and this causes slipping of the screw driver, breaking of the head of the screw, or inability to tighten the screw against the plate.

Another common cause of failure in inserting screws in bone is carelessness in the depth of the holes drilled. Even if a screw is not long enough to pass through both cortices of the bone, the hole should be drilled deep enough so that the tip of the screw does not strike bone. It is a safe rule to drill holes through the entire bone so that the screws have ample clearance. Longer screws provide stronger support than shorter screws and screws which engage both corticles of a long bone provide better anchorage than screws in one cortex alone. If long screws are used, holes should pass entirely through the bone to permit the ends of the screws to project on the opposite side.

Should Vitallium Appliances Be Removed?—While we ordinarily do not remove Vitallium appliances after fractures have healed, some surgeons prefer to because they hesitate to leave "foreign material" in a bone. This atavistic idea originates from the old fear of irritative reactions about metals in the body. Previously, metals were used which caused "electrolytic osteitis" of bone with occasional breaking open of wounds, draining sinuses, and in some cases, late fracture. Vitallium, which causes no reaction at any time, can be left indefinitely in the body with no danger of late tissue damage. It has been pointed out that many old metal appliances or pieces of metal have been left in the body for years without causing symptoms. This is true but it is probably due to the fact that these metals became encapsulated in dense fibrous tissue which prevented body fluids from coming in contact with them, or they developed a protective molecular veil ("oxygen film") which reduced electrolytic activity. In any case, wounds have healed in spite of their presence.

FIG. 5.



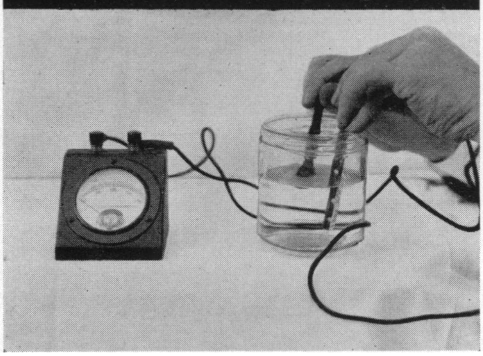


FIG. 6.

FIG. 5.—Photograph of micro-ammeter coupled with stainless steel plate in saline solution. Note that maximum current is produced.

FIG. 6.—Photograph of micro-ammeter coupled with Vitallium plate in saline solution. Note that no current is produced and the micro-ammeter registers zero.

In this series of 1,227 cases, Vitallium appliances were removed in 87 instances after the bone was healed and the need for them no longer existed. Every observer reported that the screws and plates were bright and untarnished and that the tissues about them were normal in appearance. Where there was no infection or other complications, the screws were tight in the bone and force was required to remove them. In other words, there was no evidence of the slightest erosion of bone or of any irritation of soft tissue from the presence of the Vitallium metal. In general, roentgenograms of the Vitallium appliances revealed no changes in the bone about the metal at any time after they were inserted. As Smith-Petersen remarked, "Vitallium seems to be as inert in the body as a piece of glass." Others stated: ". . . Vitallium causes the least irritation of any metal we have ever used . . ."; or ". . . even in soiled bone the soft parts healed around the plates in an astonishing manner."

Infected Wounds.—Of these 1,227 operations, where Vitallium was used, 55, or 0.044 per cent, were followed by infected or draining wounds. Of these, 46 were cases of severely compounded fractures that had been plated, one was a relighting-up of an old infected hip, and one was in a patient with phlebitis and cystitis. In the remaining seven cases, each surgeon stated that the subsequent infections were "not attributable to the metal" and that when screws were loose it was due to the infection.

Vitallium appliances not only did not cause infections in the bone but, in several instances, infected wounds gradually healed around the metal. Many surgeons, including ourselves, have applied Vitallium plates to fresh compound fractures and have seen the fractures and skin wounds heal by first intention. This advance in fracture treatment has done much to prevent the usual deformities and delayed unions after compound fractures.

CONCLUSIONS

(1) Metals which are nonelectrolytic (passive) in body fluids cause no pathologic reactions in the tissues. Vitallium which is completely passive is more inert than any alloy that has been developed so far.

(2) 1,227 Vitallium appliances used by 61 surgeons, in various parts of the country, resulted in 92.6 per cent solid bony union of fractures, 3.8 per cent delayed union, and 3.6 per cent nonunion.

(3) When Vitallium was first introduced, it was not strong enough or sufficiently malleable for general use. These defects have been corrected. In spite of former faults in the material, breaking of plates and screws occurred only 28 times in a series of 1,227 cases, or only 2.3 per cent of the total. This percentage has steadily decreased as the alloy has been improved.

(4) Screws made of Vitallium were originally too fragile for all uses. The new screws are amply strong for any type of operation and the wood-type screw has been found to be most satisfactory.

(5) On the occasions when Vitallium appliances have been removed, the surrounding bone has shown no erosion or discoloration.

(6) When infections occurred in any cases in this series, they could be traced to such causes as compound injuries, septicemia, *etc.* In other words, no wound became infected *because* of a Vitallium appliance.

(7) On the basis of this study, it has been found that Vitallium has sufficient strength and inertness to be perfectly suited to all requirements of bone surgery.

(8) In metals or alloys the phenomena of passivity are apparently closely linked to their degree of inertness under corrosive conditions, and comparative determinations of current flow with a micro-ammeter, using some common third metal as an anode, give useful indications of their probable tendencies toward reaction *in vivo.* Metals or alloys that give relatively high readings are likely to cause a corresponding disturbance in bone or tissue. Above all, two metals or alloys of different character must be avoided, such as a plate of one kind and screws of another, in the same operation.

(9) In any new metal, tensile strength, hardness, shape of appliances, *etc.,* are all comparatively unimportant and secondary to the vital fact that the material must be passive (nonelectrolytic) in the tissues.

(10) A great deal of study and development is going on in the field of

stainless alloys. The theoretical work of Uhlig and Wulff at M.I.T. has thrown additional light on passivity, and disclosed the limitations of the oxide film protection theory. This newer conception which deals in terms of the structure of the atomic lattice shows, more rationally, the importance of the rôle of hydrogen in the loss of passivity and explains why the addition of molybdenum to the 18–8 type of material, has increased its resistance to corrosion attack, particularly of the localized form resulting in pits. Maybe it is possible that further developments will produce material more suitable than the best of the present available stainless steels.

(11) We will continue our search for an ideal alloy for use in the body and enlist the aid of chemists and metallurgists to help discover such an alloy. We hope some material can be discovered which has the proper strength, ductility, and passivity for all uses in the body. So far, Vitallium is the only metal we have found which is completely passive in body fluids. The final choice of material must possess such complete passivity.

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