CATHODE COMPOSITION AND ELECTRICAL OSTEOGENESIS

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We are continuing to study the influence of electrode composition on cathodically enhanced osteogenesis. The hope is that such information might give some clues to the mechanisms by which bone is elaborated near electrically active implants as well as maximize efficiency and safety for use in the treatment of non-united fractures, etc. Presently, we report a study of some electrochemical characteristics of several implantable metals in vitro and in vivo, and comcompare these to the conditions at which osteogenesis has been electrically enhanced. We have also attempted to evaluate these metal cathodes by implantation into the medullary canal of the rabbit femur.

Figure 1 shows typical 'DC' current-potential characteristic curves obtained in cell culture medium for some pure metal cathodes. The alloys, Pt-Ir(10%), SS-316L, Vitallium F-90 and Elgiloy, were also tested. In general there were large differences in the conductivity of the different metal interfaces under such conditions. Pt and Pt-Ir were most efficient and Ta and Vitallium the least. Similar behavior was found when current instead of potential was controlled and also when the experiments were performed in living rabbit muscle.

The dark squares in Figure 1 mark conditions for which electrical osteogenesis has been reported to occur with these electrodes in animals or man (1). The open circles mark conditions which have been reported to cause necrosis. In general, necrotic reactions occurred for potentials more negative than -1.0 volts (ref. to SCE) and for current densities above 5 microamp./mm^2. In this region it is known that Faradaic reactions involving H_2 evolution, etc., and pH changes occur (2).

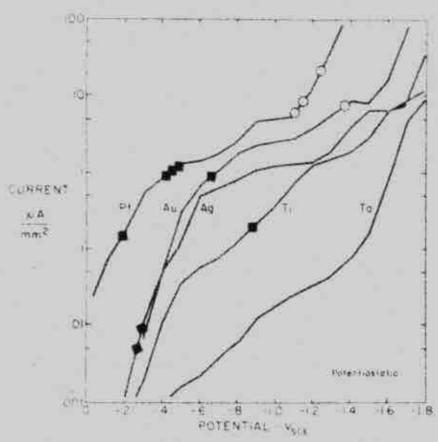

Figure 1: Current density vs. cathode potential (potentiostatically with ref. to saturated calomel) in Dulbecco's medium +10% fetal calf serum. Steady state data at 5 min. with 100 mV steps. Electrodes as wires with acetone cleaning only. Mean of duplicate runs at 37ºC.

Furthermore, by removing O_2 from the test chamber, it was found that between 0 and -1.0 volts, currents were drastically reduced for all metals. This indicates the probable role of molecular O_2 in current transport at the interface in the osteogenically active potential region and, by implication, the role of its reaction products in stimulating osteoblastic activity.

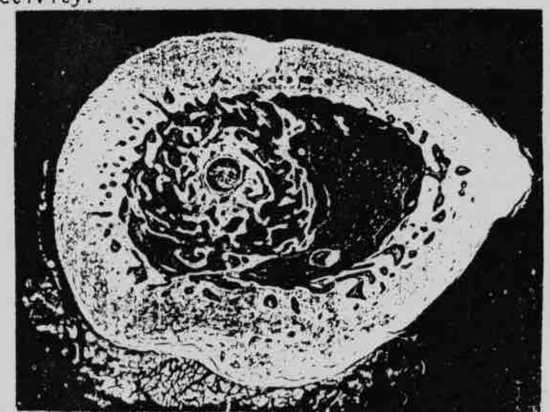

Figure 2: Rabbit femur, platinum cathode, 20 nano-amperes/mm^2, 3 week implant.

To see if any of the above observations would be reflected in vivo, we have begun a series of implants in the rabbit femur with different metal cathodes. In this first group, Pt, Au, Ag, Ti, SS-316L, Vitallium F-90 electrodes were inserted in the mid-shaft via a small hole in the distal metaphysis and activated by implanted constant-current circuits set at 20 nano-amperes/mm^2 for 3 weeks. Six animals for each metal were used, each with contralateral sham controls. Histological sections showed a moderate bone elaboration around most experimental and control electrodes, except that more extensive growth was seen for active Pt and Vitallium cathodes (Fig. 2). Thus at this current level one seems to be close to background levels of bone reaction and further implants at higher currents, where metal differences and active/control differences might be more pronounced, are in progress.

1. J.A. Spadaro, Clin. Orthop. Rel. Res. 122, 325 (1977).
2. C.T. Brighton, et al, Annals N.Y.A.S. 238, 314 (1974).

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