'A Theory of Electromagnetic Interactions with Bone and Connective Tissue'

by

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The use of magnetic fields to aid the healing of long bone fractures have long been practiced with good results, particularly so when applied to non unions. The method of interaction of the field with the bone has never been well explained, however work by Becker has brought some explanation with regards to the action of piezo- electric charges and the way they are processed within bone structures. These present an osteoblast attracting or regeneration charge in areas of injury or stress. This article is intended to go further and identify possible interactions of dynamic magnetic fields in both healing of fractures and attracting bone cells to areas under treatment.

Becker identified and established the existence of perineural currents, which flow through myelin cytosol in a conventional type of electric current fashion. Each segment of the myelin sheath is in contact with the each other at the ‘Nodes of Ranvier’. Micro apertures between them allow a flow of charge carriers along their length. This is different to nerve impulses which are due to a wave type sodium inflow / chlorine outflow along the fibers. The brain is the source of negatively charged particles, which form the basis of such currents. A continuous loop of efferent and afferent nerves normally completes the circuit back to the brain. An injury to soft tissue or bone exposes the nerve endings in such a way that minute currents then flow across the injury site from damaged efferent to afferent nerves. Such currents are termed ‘currents of injury’. These in themselves are sufficient to trigger healing at the site. In long bones, the marrow produces DNA bearing, immature blood cells. The minute injury current triggers a process of dedifferentiation of these blood cells, which transform to become bone. Under normal conditions, therefore, the healing of fractures takes the form of regeneration as opposed to repair.

Non-union fractures may be ones that have damage to the nerve endings at some distance away from the actual fracture site. This could occur through additional stress fractures, disease or infection. The distances between the exposed nerve endings of the afferent nerves to the efferent may be too great to allow a sufficiently large enough ‘current of injury’ to flow. Hence the regeneration process does not occur. It also possible that delayed union may be caused by the need for neural repair and re-growth to be well established towards the fracture site before currents of injury are sufficient to trigger the bone regeneration process.

An American Orthopaedic surgeon, Dr Gus Sarmiento, suggested that fractures are aided in their healing process by slight movements at the injury site. Such movements are believed to encourage blood flow to stimulate the formation of callus. Now it may be speculated that the compressive action between the fracture segments could induce small currents in the bone. Such currents are termed piezo electric. This is a phenomenon that occurs when crystal structures are forcibly compressed or extended. A voltage appears across the face of the crystal structure during the dynamic phases of both compression and extension. The polarity, therefore, may present a negative aspect, adding to the current of injury during compression but then counter it with an opposite, positive one during its extension back to normal. Therefore the voltages would effectively cancel each other out. Becker's work suggested that bone material has properties such that they filter out the positive voltage so that only the compressive, negative ones are left. These will, therefore, only ever add to the current of injury. This may be sufficient to speed up initial regeneration of the bone. This would be in keeping with Woolff's Law, which states that bone growth is increased in areas of stress.

The voltage filter mentioned above is due to the bonding together of two crystalline forms making up bone structures. Within these crystal structures are different types of 'free' charge carriers. Anyone familiar with solid states electronics would know these as 'N' (negative) and 'P' (positive) type charges in semiconductors. Osteones comprising collagen and apatite are bonded together by copper ions. The junction between the two brings together the 'N' type collagen tightly to the 'P' type apatite. When in contact, some of the positive 'N' carriers cross into the apatite and vice versa. A 'PN' junction is formed which has the properties of allowing current to flow one way only, that is, 'N' electrons can only flow one way and the 'P' charges the other. This occurs only if the biased nature of any piezo electric voltage is correctly orientated. The opposite voltage is effectively cut off, as current cannot flow in the opposite direction.

This phenomenon would not only apply to injuries but also to where bone is stressed. Osteoblasts, formed from osteo-progenitor cells at the periosteum, are attracted directly to the area producing piezo-electric activity through the haversian canals. Where voltages do not exist or are dormant, osteoclast action removes bone material and hence problems of osteoporosis and osteo-malacia may occur. Where movement is not possible for any reason, pulsating magnetic fields may provide an alternative method of causing the minute voltages similar to the natural piezo-electric ones. To understand how this can happen one has to take a look in simple terms at the production of magnetic fields. The whole subject of magnetism is extensive and a deep study is beyond the scope of this article, however, there are some readily understandable concepts. Magnetic fields are produced when charged particles such as electrons or ions are moving uniformly in a straight line, i.e. through a conducting wire or crystalline structure. Conversely if a magnetic field is moved through a wire or crystal structure, then the charged particles in that structure are caused to move at right angles to the movement and in a direction dependant on whether the field is increasing or collapsing. Static fields have no effect. This phenomenon is termed 'electromagnetic induction'. The main requirement is that there is some dynamic interaction, i.e. relative movement between the field and target tissue.

With bone, the collagen/apatite 'PN' junction will allow 'N' electrons to move in one direction across the junction and 'P' charges in the other. When a dynamic magnetic field is applied to the structure, the N and P charges cross the junction. This causes a charge to appear biased in one way when the field is moved in one direction due to the free movement of charges across the junction, but effectively filtered when the movement of the field is in the opposite direction. This induced charge therefore mimics the charge caused by natural piezo-electric activity within the bone and may attract osteoblasts to the target area. The same process would occur with non-union fractures. The electro- magnetically induced micro currents would only aid the currents of injury. This may possibly raise the current to the threshold required to trigger regeneration and eventual union of the fracture.

This article presented a possible explanation for the effectiveness of pulsed magnetic therapy to mimic that which would naturally occur in the bone. Robert O Becker MD has carried much of the background work out over many years. Works on animals here in the UK have confirmed the efficacy of pulsating magnetic fields both with bone and soft tissue injuries, as well as demonstrating the beneficial effect on nervous systems in both the reduction of pain and psychological conditions.