EXPERIMENTAL AND CLINICAL APPLICATION OF CARBON FIBRE AS AN IMPLANT IN ORTHOPAEDICS

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If any material is to replace another as an implant in orthopaedics it must not only demonstrate the advantages of the material it is to replace but must also show additional advantages; these may be either mechanical or biological. We feel that in theory at least, carbon may be such a material. It can be made in a number of shapes and forms. It can be manufactured to differing strengths and flexibility. Because of its very nature it is in theory at least, totally inert.

In the first series of experiments the tendo-Achilles in sheep was excised and replaced with a double plaited strand of flexible carbon fibre tow. In a controlled series of sheep the tendo-Achilles was excised and either replaced with nylon or not replaced at all. The control sheep never walked satisfactorily, whereas the sheep in which the carbon fibre tendo-Achilles had been inserted walked normally within two to three weeks. Examination of the carbon implant at six months showed that there was a massive fibrous reaction in the region of the implant which appeared to mimic both in shape and size a new tendon. It was virtually impossible to see any evidence of the implant at all because it had become enveloped in new tendon-like tissue.

A further series of experiments was carried out in rabbits in which the tendo-Achilles was replaced with filamentous carbon fibre. It was found that the breaking strain of the normal tendon on the opposite side was between 10 and 20 Kgms. Breaking strain of the replaced tendon rose from 2 Kgms at insertion. The new tendon did not actually snap but in fact tore out from the muscle at the proximal end. By six weeks however the tendon had become fully enveloped in what appeared to be new tendon-like tissue and the breaking strain had reached that of the other side.

A number of other experimental models have been tested. One such was to create large incisional hernias in the abdomens of sheep. These were repaired with carbon fibre woven in the form of a mat with satisfactory results. Another experiment was to replace one of the flexor tendons in a chicken. While this apparently functioned as a normal tendon for two to three weeks, it rapidly ceased to move. Histological examination showed ingrowth of new tissue, not only from the ends, but also from the sides and this suggests that carbon may not be suitable as a flexor tendon replacement in its present form.

In order to test the suggestion that the actual presence of the flexible carbon was somehow stimulating or inducing a new tendon to form we replaced the only tendon in the body which lies free from adjacent tissue. The anterior cruciate ligament in sheep was excised and replaced with carbon fibre. At six weeks the macroscopic appearance was that of a new but slightly thicker anterior cruciate ligament. Histological examination of the new tendon showed that while the carbon fibre was still present, the individual strands were widely separated by tissue which was histologically similar in every way to that of normal tendon.

Histological examination of soft tissues proximal to the implant showed heavy concentrations of carbon in the soft tissue adjacent to the regional nodes and the regional lymph nodes themselves were seen to have a black rim which contrasted strongly with the lymph nodes on the opposite sides. Cross section of one such lymph node taken from the para-aortic group on the carbon implantation side shows that there is a heavy concentration of carbon within the node. These nodes appear similar in every way to those found in coalminers and city dwellers in that the black appearance of the node clearly seen by naked eye is in fact due to the carbon. This appears to cause no detrimental effect. In other tissues taken from animals killed two years following implantation, there is no evidence of carbon either in lungs, spleen, liver or elsewhere. If carbon was found it is always found in the nearest major adjacent proximal lymph nodes.

It is our suggestion that flexible carbon fibre may act as the ideal implant material for the following reasons.

It is inert. This statement can be substantiated by histological examination of sections following implantation in which there is little more than the inflammatory reaction normally expected in any injury.

It is strong. This is demonstrated by the ability of the carbon to support a walking sheep within days of implantation.

Its strength increases. This is demonstrated by the experiments in which the strength was seen to increase as time went by. This increase in strength corresponds with the stimulation of an ingrowth of new tissue into the carbon fibre scaffold.

Lastly, it possibly begins to disappear from the site of implantation. We feel that the formation of new tendon-like tissue as opposed to primitive scar tissue is due to the comparatively early fragmentation of the individual carbon fibre filaments. This produces a stress reaction in the new tissue resulting in the formation of tendon of the type demonstrated.

In order to test the clinical application of this material we have so far reinforced the medial ligaments of an unstable knee and have similarly reinforced the capsule of a ruptured carpo-metacarpal joint. Early impressions are that this material behaves in the human in a manner similar to that in the animal experiments described.