USES AND PERSPECTIVES OF BIOMEDICAL COMPOSITES

CLAUDIO MIGLIARESI
Department of Materials Engineering, University of Trento, Italy

Properties, design, capabilities and easiness of fabrication make polymeric based composite materials the ideal candidates for the construction of tailor made biomedical prostheses (fig. 1). The appropriate combination of fibres and matrix can reproduce, in fact, mechanical properties of most biological tissues, so offering undoubted advantages in terms of biomechanical requirements of biocompatibility of the prosthesis. Based on these principles many examples have been reported in the literature on composite based model prostheses, such as for artificial tendons or ligaments, blood vessels, bone substitutes and fixation plates, hip prostheses and others (fig. 2). For instance, bone plates made of composite materials can match elastic properties of bone better than metals (fig. 3 and 4), so reducing the stress shielding effect reported in the literature. As reported in fig. 3, in fact, metals used in orthopaedics display an elastic modulus of about 200 GPa, well above the 17 GPa of cortical bone. Vice versa, by changing reinforcement type, geometry, and content, plates made of composites reported in fig. 3 (sfc, kfrp and cfrp stay for short fibre, long kevlar fibres and long carbon fibre composites, respectively) can have elastic moduli in the whole interval represented by the column.

For this application, however, one should be aware of the fact that any comparison should be made in terms of stiffness (i.e. elastic modulus times a geometric factor which depends on the loading mode). The same concept applies to hip prostheses, where finite element analysis indicates the advantages offered by composites, in terms of more homogeneous stress distribution (fig. 5 and 6). In this case the prosthesis can be designed by accounting its effect on the stress pattern of cortical bone of femur.

Furthermore, stress strain curves of tendons and ligaments can be well reproduced by rubbery matrix long fibre reinforced structures (fig. 7). For other applications in the biomedical field, such as external artificial limbs, lightness and rigidity can represent enormous advantages (fig. 8).

The use of composite structures appears to be even more promising for the construction of biodegradable prostheses, where high modulus or strength biodegradable fibres can impart the desired higher rigidity to existing weak biodegradable polymeric matrices. Polyglycolic or polylactic fibres reinforced biode-

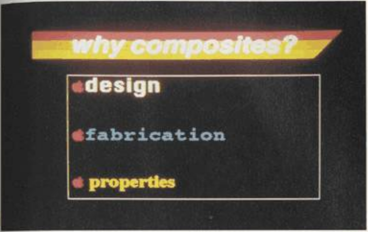

Fig. 1 - Advantages offered by composites.

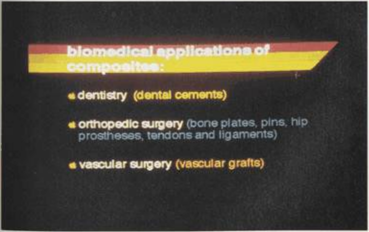

Fig. 2 - Main biomedical applications of composites.

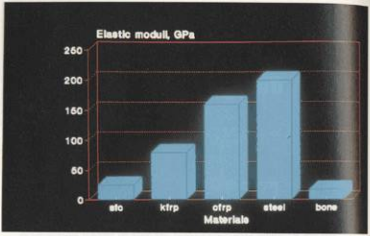

Fig. 3 - Comparison of the elastic moduli of bone, steel and the ranges of elastic modulus values achievable with short fiber composites (sfc), long kevlar (kfrp) and carbon (cfrp) fiber composites.

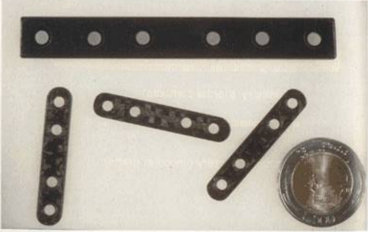

Fig. 4 - Some bone plates made by carbon fiber composite materials.

Fig. 5 and 6 - Finite element analysis picting the stress distribution of the femur cortical bone without and with a composite hip prosthesis.

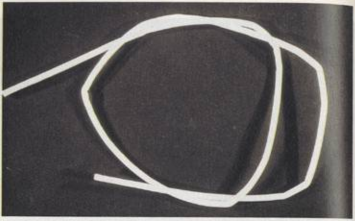

Fig. 7 - A synthesis tendon made by polyester fibers/ poly-2-hydroxyethylmethacrylate matrix.

Fig. 8 - An artificial limb made by composites.

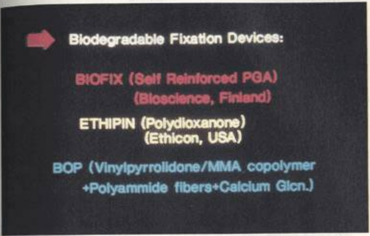

Fig. 9 - Present commercial applications of composite biodegradable fixation decives (Biofix, BOP).

gradable polymers, or other fibre reinforced matrices, are examples already used to construct small bone fracture fixation devices (fig. 9).

In spite of their potential benefits still some doubts exist on the use of composites. Some of them are however due to non favourable first clinical results achieved with composites made prostheses, where some problems (such as wear) have not been taken into account. Nevertheless, appropriate design and suitable choice of the application should progressively extend the biomedical use of composite materials.