HYDROLYTIC DECOMPOSITION IN A POLYAMIDE/PDMS COMPOSITE FOR ORTHOPAEDIC USAGE

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Introduction

A successful tissue engineering product must necessarily result from combining several disciplines dealing with mechanical properties, the interaction of the implant with the surrounding tissue, and also practical clinical experience. With composites consisting of polymer reinforcement and a polymer matrix with the possibility of selecting the volume ratio of the fiber reinforcement to the matrix and also a suitable orientation, mechanical properties identical with those of human bone can be obtained [1]. The reason for their wide use in various medical applications is mainly the availability of materials with various properties in various forms and compositions as well as the fact that they can be hardened directly into the required shape or structure with the most suitable fiber orientation. Their biocompatibility and mechanical properties can also be enhanced by inserting a bioactive component into the matrix. Our study reported in [2] dealt with preparing fiber composites based on an aliphatic or aromatic polyamide and on a polydimethylsiloxane (PDMS) matrix modified by calcium phosphates. We also reported on their mechanical properties and moreover their biocompatibility [3].

In the case of polymeric composites, it is important to study their degradation upon exposure to environmental conditions. Moisture uptake can lead to reduction of mechanical properties and change of dimensions [4-5]. The hygroscopic nature of aramid fibers has to be taken into account. It has been concluded that poor resistance to moisture absorption is one of the drawbacks of aliphatic or aromatic polyamide fabric composites [4]. It is important to study their moisture absorption behavior in order to estimate not only its influence on the mechanical properties of the composites, but also how this moisture uptake can be minimized. The aim of this study was to investigate the moisture absorption behavior of an Aramid/PDMS composite as a result of short-term immersion in simulated body fluid (SBF) at 37°C for 28 days. A study was made of the influence of three kinds of chemical and thermal treatments of Aramid fabric on the moisture absorption and mechanical properties of the prepared composites.

Materials and methods

Four kinds of composite materials differing in the chemical treatment of the fabric were prepared. All composites were based on an Aramid reinforcement (55 vol.%, Aramid balanced fabric, based on aromatic polyamide fibers HM 215, Hexcel, FR) and a PDMS M130 matrix (Lucebni zavody Kolin, CR). The Aramid fabric was chemically treated by immersion in three different media: i) by immersion in xylene for 24 hours (X) as a representative of organic solvents, ii) by immersion in 10 wt% HNO_3 and 33 wt% H_2O_2 solution at 110°C for 4 hours (K) as a representative of an acid environment, and iii) by immersion in 10 wt% KOH and 33 wt% H_2O_2 solution at 110°C for 4 hours (L) as a representative of an alkali environment. After these procedures, the fabrics were washed in deionized water several times until neutral pH was reached and then dried at 110°C for 4 hours. Treated and untreated (O) layers were impregnated and then placed into the curing mould ([0°/90°]) and finally cured under a pressure of 1.1 MPa at 225°C in an air atmosphere for 4.5 hours and postcured under a pressure of 1.1 MPa at 250°C for 4 hours. Moisture absorption and mechanical tests were performed on specimens of (60x6x2) mm (6 samples from each). Prior to the experiments, all specimens were dried until a constant weight was attained. The specimens were immersed in SBF (ISO 23317) at 37°C for 28 days. The moisture uptake was calculated as the weight gains related to the weight of the dry specimens. The ultimate strength in bending and the modulus of elasticity in bending in the direction of the fiber axis were determined by a four-point bending set-up using the Inspekt 100 HT material tester (Hagewald & Peschke, Germany), in accordance with ISO 14125. Unimmersed (dry), immersed, immersed and re-dried (until a constant weight was reached) samples were measured. A statistical analysis for all tests was carried out by nonparametric analysis of variance, at a significance level of 0.05 (Kruskal-Wallis test, Mann-Whitney as a post hoc test), and the confidence intervals for the mean values were calculated at a significance level of 0.05.

Results and discussion

The lowest moisture uptake values after 28 days of immersion in SBF were reached in the case of K composites (FIG. 1), where all the values display statistically significant differences. The flexural properties of the four composites upon moisture saturation were tested and compared with those of the corresponding dry and re-dried samples; the results are summarized in FIG. 2 and FIG. 3.

The strength in bending was shown in all cases to be a strong function of the moisture content of the sample. The results show that the moisture effects are substantial: losses of approx. 21% (K) < 31% (X) < 34% (O) < 46% (L) in the sample strengths were observed at their moisture saturation, in comparison with their dry condition. A comparison of the immersed and re-dried samples indicates that there is irreversibility of the acting mechanism in the case of samples K and L, probably just due to weakening of the reinforcement-matrix bond. In most cases, the modulus of elasticity in bending is also influenced by the moisture content. From this point of view, in the case of samples K, the modulus is not affected by moisture absorption.

The degradation of fiber reinforced polymeric composites is mainly caused by the deterioration in the load bearing ability at the interface resulting from failure of the interfacial bonds [4]. Matrix or fiber degradation and matrix cracking may also contribute to degradation of the composites. Our previous study (reported elsewhere [6]) on glass fibers/PDMS composites shows that PDMS is not prone to degradation in a tissue culture medium. In the case of aramid/PDMS composites, interface debonding was probably mostly responsible for the mechanical degradation. It is necessary to verify this assumption by further experiments, namely determining the extracted silicon (possible PDMS degradation) and determining the influence of immersion on the inner composite structure by image analysis.

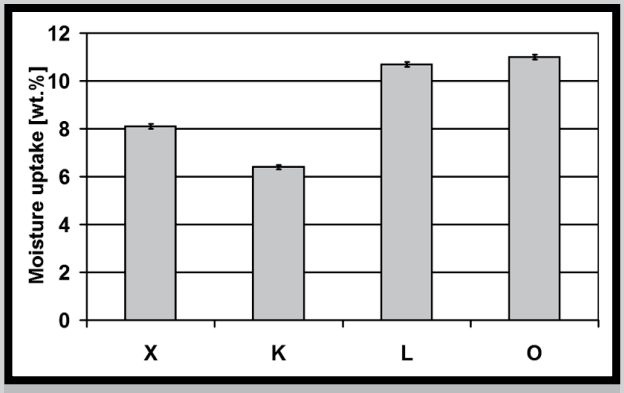

FIG. 1. Moisture uptake of the studied composites, all values show statistically significant differences (0.05).

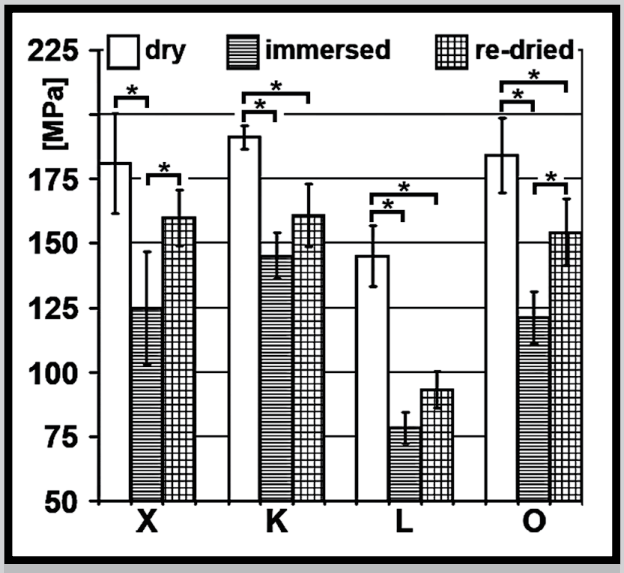

FIG. 2. Ultimate strength in bending of the studied composites. * denotes statistically significant differences (0.05).

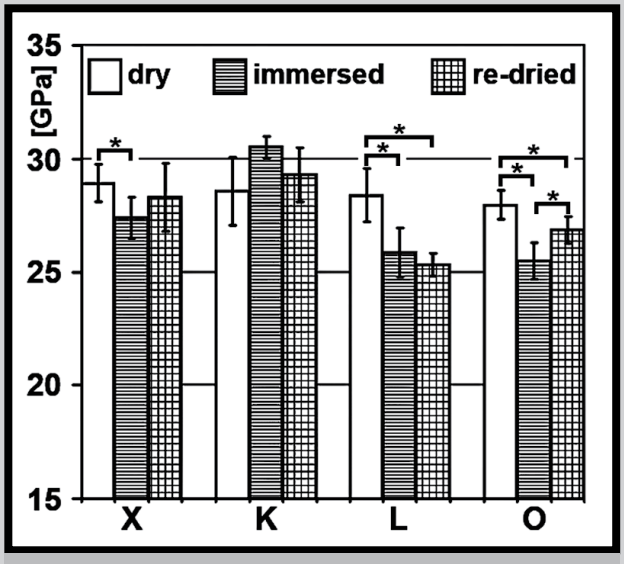

FIG. 3. Modulus of elasticity in bending of the studied composites. * denotes statistically significant differences (0.05).

Conclusions

This study has investigated the effect of three kinds of chemical and thermal treatments of aramid fabrics on the moisture absorption and mechanical properties of polymeric composites due to short-term immersion in SBF. The results have demonstrated that surface treatment of aramid fabric changes the moisture absorption trend. When the aramid fabric was immersed in 10 wt% HNO_3 and 33 wt% H_2O_2 solution at 110°C for 4 hours, both moisture sorption and mechanical degradation decreased with respect to the untreated composite.

Acknowledgements

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