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Nanostructured 3D collagen-nanotube biocomposite for future bone regeneration scaffolds

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Abstract – In this work we describe a collagen-carbon nanotube composite with enhanced and unique properties which has the potential to be used as a scaffold for tissue regeneration. Because this biocomposite incorporates the advantageous properties of both collagen and carbon nanotubes, it has most of the required characteristics that an ideal biomaterial needs in order to be used as agent of osteoinduction. This biocomposite is bioresorbable and biodegradable and has a desirable mechanical rigidity while maintaining a 3D nanostructured surface. Tuned stability and swelling is also achieved under fluid environments by varying the amount of carbon nanotubes incorporated into the composite.

New advances in bone tissue engineering have motivated the search for new materials that are biocompatible with the different bioactive functions which actually occur in live, growing tissues [1]. The ideal scaffold also requires a desirable mechanical rigidity and a porous 3D structure which can provide maximum integration with cells and body fluids, plus have a nanostructured surface which facilitates the adhesion of cells [1]. Additionally, the biomaterial could also be modified so that it contains functional moieties (e.g., growth factors) that promote and stimulate the growth of new tissue [2].

One of the main goals of developing a collagen/CNT composite is to improve the poor mechanical properties of collagen, which have hindered a wider application of this molecule in bioengineering. To asses this improvement, stress-strain curves were performed from both types of pure collagen and composites made with 4% wt of SWCNT-COOH (Fig. 1). The enhancement of the mechanical properties (tensile strength) was found for the composites in comparison with their pure counterparts using both collagens. The pure collagen from rat showed a poor stress resistance. When CNTs were added to the matrix, the stress resistance increased about 3 times. The pure collagen from cattle is more resistant to stress and the presence of CNTs also increases the resistance of the composite, but to a lower extent as compared to rat collagen. Rupture tension experiments showed that composites made with rat collagen is more resistant than composites made with cattle collagen.

Figure 2 depicts SEM micrographs for pure collagen and composite (4 wt% of CNTs) after exposure to physiological concentrations of Ca^{2+} and PO_4^{-3} ions for one and four weeks. Interestingly, after exposure for 1 week no evidence of HA crystals was found for the pure collagen material, while formation of some HA crystals was clearly observed on the collagen/CNT composite. After exposure for 4 weeks, both materials were covered with HA crystals (verified by IR spectroscopy, Fig. 2 left panel). However, it must be noted that different morphologies were found for the two materials. On the composite, in addition to the formation of HA crystals over the entire composite, we consistently found very large HA crystals (Fig. 2(d)). These results indicate that not only does the nanostructure surface of both materials enable the formation of HA crystals, but also that, qualitatively, an increased induction of HA crystals was observed for the composite. Suggesting that the increased mechanical rigidity combined with the enhanced nanostructured character of the composite are the traits responsible for this improved performance.

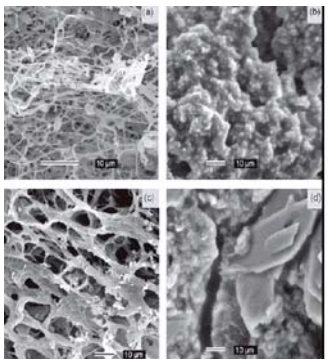

Figure 1 Stress assay for composite (4 wt% CNTs) and pure collagen from bovine (a) and rat (b). Rupture-tension assays (c) showed that composite from rat collagen is more resistant than composite made with bovine collagen (P<0.05)

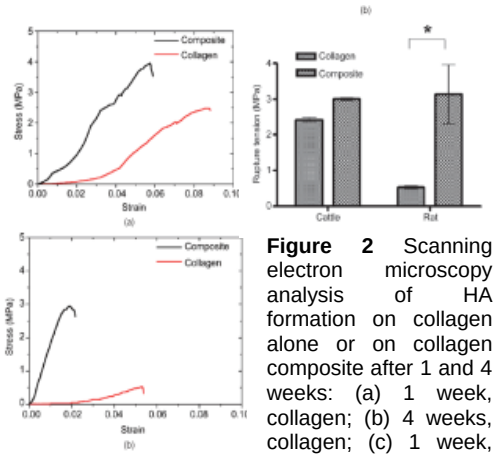

Figure 2 Scanning electron microscopy analysis of HA formation on collagen alone or on collagen composite after 1 and 4 weeks: (a) 1 week, collagen; (b) 4 weeks, collagen; (c) 1 week, collagen composite; (d) 4 weeks, collagen composite.

References

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